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Influence of Drip Irrigation and Polyethylene Mulch on Production and Economics of Broccoli

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Abstract A field study was carried out during *rabi* season of the 1012-13 to standardize the drip irrigation levels and mulching on growth, maturity, yield, water-use efficiency and cconomice of broccoli. Seven irrigation levels based on pan evaporation (E_{pam})from a USWB Class-A open pan i.e. 100, 80 and 60% of PE replenishment daily as well as alternate day along with surface irrigation were tested under two levels of mulching viz., no mulch and with black plastic mulch in a Two Facrorial Randomized Block Design replicated thrice. All growth characters as well as yield and yield attributes were found significantly higher with 100% PE replenishment daily under black plastic mulch. The highest Water use efficiency (WUE) of 13.92 q ha^{-1} cm^{-1} was observed with 60% PE replenishment daily through drip under black polyethylene mulch and lowest (6.02 q ha^{-1} cm^{-1}) with traditional practices i.e. surface irrigation under unmulched condition. Highest gross return (`300795.00 $ha^{-1}$), net return (`214969.00 ha^{-1}) and benefit - cost ratio of 3.50 was obtained in 100% PE replenishment daily under black plastic mulch.

Keywords Broccoli, Drip irrigation, Black plastic mulch, Water use efficiency, Economics.

Introduction

Sprouting broccoli (*Brassica oleracea* var *italica* L.), a highly nutritious vegetable crop belongs to the family Brassicaceae and is an important member of cole crops. Due to increasing awareness of its high nutritive values and demand in cities, cultivation of broccolli is gaining popularity in India. Availability of irrigation water in successful broccoli production is an important aspect and shortage of water is detrimental for head development and drastically reduces the yield. Rapid population growth and need of water for domestic and industrial purpose envisages the needs for the judicious use of water in agriculture. Thus, it is of prime importance to use right amount and frequency of irrigation water to achieve the maximum production levels. Commonly used irrigation method in India i.e. surface irrigation has considerably low efficiency of 33%, which can be increased to substantial level by using advanced irrigation methods like drip irrigation system. The merit of drip system lies in applying the required quantity of water in the root zone of the crop through network of tubings.

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The drip irrigation method is advantageous over traditional methods of irrigation as it provides maximum use of available water, no water being available to weeds, increase crop yield, decreased tillage, high quality product, less incidence of insect - pests and diseases, lower operating costs and better use of irrigation water. Research available so far revealed that the use of drip irrigation with black plastic mulching in vegetable cultivation is one of the most efficient management tools for conserving the soil moisture, improves the hydrothermal regime of the soil as per crop need and increase the yield. Mulching also have positive influence by providing favorable temperature for crop growth and development, improving produce quality, water conservation, weed management, and help in getting early and higher yield [1].

Keeping all the points in view, the importance of judicious use of irrigation water and benefits of drip irrigation and black plastic mulching the present investigation was planned to optimize the irrigation requirement of broccoli under black plastic mulch and unmulched condition i.e. open field condition compared to surface irrigation.

Materials and Methods

The present investigation was carried out at Vegetable Research Center (VRC) of G. B. Pant University of Agriculture and Technology, Pantnagar U.S. Nagar, Uttarakhand, India. Pantnagar lies in 'tarai' plains of food hills of Shivalik range of Himalayas at 29^{o} N latitude and 79.29^{o} E longitudes with an altitude of 243.8 m above mean sea level. The pan evaporation and rainfall data during the period of experimentation were recorded at the meteorological observatory. The experiment was laid out in Two Factorial Randomized Block Desing with three replication. The first factor during the study includes black plastic mulch and unmulched condition. Whereas, seven irrigation leaves i.e. 100, 80 and 60% PE replenishment daily as well as altermate along with surface irrigation comprises the second factor. One month old broccoli seedlings gown on raised beds were transplanted on 22nd November on a raised beds at a spacing of 50 cm × 50 cm. The plastic mulching is done with black plastic film of 25 micron thickness. The amount of water applied to broccoli i.e. daily or alternate day was calculated using mean pan evaporation data obtained from USWB class. A open pan separately for each treatment and amount of applied water was controlled with gate values. Observations for vegetative parameters were recorded by using standard techniques in broccoli. The crop was harvested manually from 31st January to 18th February, depending upon the maturity of heads. In order to assess the economic viability of different system under variable irrigation, both fixed (interest on initial cost and depreciation on the system) and operating cost including wages of labours incurred since seed sowing in nursery to final picking along with expenditure on marketing and transportation. The gross and net returns were worked our accordingly by taking cost of cultivation and average sale price broccoli during the growing period. The data recorded were analyzed and were presented.

Results and Discussion

Growth characters

The data depicted for growth characters (Table 1) revealed that all the growth characters viz., plant height, plant spread, leaf area and stem diameter were significantly influenced by both the factors i.e. irrigation levels and mulch used during the study. Among the irrigation levels, irrigating broccoli at 100% of PE replenishment daily significantly increased the plant height (48.39 cm), plant spread (77.83 cm), leaf area (474.83 cm^2) and stem diameter (37.74 mm) by the order of 13.6, 10.2, 16.5 and 24.2% compared to the surface irrigation, respectively. Gradually decreasing the amount of irrigation form 100 to 60% of PE replenishment and to surface irrigation significantly reduces the vegetative growth. The increase in vegetative growth with increase in irrigation levels might be due to higher frequency of water managed through drip irrigation, which provides precise amount of daily requirement of water to the root zone of plant and maintains proper soil moisture potential in the rhizosphere to reduce plant water stress [2], which is expressed in terms of more plant growth. In contrast, least plant growth in surface irrigation might be due to alternate excess and moisture stress under surface irrigation temporarity decreased aeration in the root zone and

Table 1. Effect of different irrigation levels and black polyethylene mulch on growth, maturity, marketable yield, yield components and WUE of broccoli.

Treatments	Water applied (cm)	Plant height (cm)	Plant spread (cm)	Leaf area (cm^{-2})	Stem dia. (mm)	Head initiation (days)	Dia. of head (cm)	Net head weight (g)	Yield (q ha^{-1})	WUE (q ha^{-1} cm^{-1})
Irrigation level (PE replenishment, %)										
100 daily (I_1)	20.36	48.39	77.83	474.83	37.74	57.25	12.56	444.00	177.60	8.72
100 at alternate day (I_2)	20.36	47.27	77.17	466.35	36.78	56.77	12.14	432.00	172.80	8.44
80 daily (I_3)	16.29	46.71	75.55	454.26	34.28	56.22	11.97	416.00	166.40	10.21
80 at alternate day (I_4)	16.29	46.27	74.08	446.19	33.34	55.42	11.52	399.33	159.73	9.80
60 daily (I_5)	12.22	46.06	73.97	437.63	32,21	54.72	10.96	377.33	150.93	12.35
60 at alternate day (I_6)	12.22	44.14	72.95	430.59	31.19	54.23	10.74	368.00	147.20	12.04
Surface irrigation (I_7)	20.36	42.57	70.61	407.70	30.38	58.14	10.58	343.00	139.76	6.86
CD (0.05)		0.84	0.90	41.21	2.66	1.40	0.54	12.90	4.30	0.46
Mulching										
Without mulch (M_1)		44.32	72.67	402.84	30.71	58.32	10.95	348.76	139.50	8.57
Black polythene mulch (M_2)		47.51	76.52	487.89	36.70	53.89	12.04	445.43	178.90	10.99
CD (0.05)		0.45	0.48	22.03	1.42	0.74	0.29	6.90	2.30	0.24
Interaction										
I_1M_1	20.36	47.44	76.17	434.30	34.03	59.27	12.09	386.67	154.67	7.59
I_2M_1	20.36	45.89	75.67	424.22	32.86	58.80	11.48	374.67	149.87	7.36
I_3M_1	16.29	45.33	74.00	412.81	31.20	58.37	11.29	368.00	147.20	9.03
I_4M_1	16.29	44.67	72.28	400.70	30.59	57.63	10.73	353.33	141.33	8.67
I_5M_1	12.22	44.56	71.61	391.30	29.00	57.17	10.57	329.33	131.73	10.78
I_6M_1	12.22	41.78	70.05	384.89	28.89	56.83	10.30	322.67	129.07	10.56
I_7M_1	20.36	40.56	68.89	371.67	28.43	60.17	10.17	306.67	122.67	6.02
I_1M_2	20.36	49.33	79.50	515.37	41.45	55.23	13.07	501.33	200.53	9.84
I_2M_2	20.36	48.64	78.67	508.48	40.70	54.73	12.80	489.33	195.73	9.61
I_3M_2	16.29	48.08	77.11	495.70	37.37	54.07	12.65	464.00	185.60	11.38
I_4M_2	16.29	47.87	75.89	491.67	36.09	53.20	12.31	445.33	178.13	10.92
I_5M_2	12.22	47.56	76.33	483.96	35.43	52.27	11.35	425.33	170.13	13.92
I_6M_2	12.22	46.51	75.84	476.30	33.50	51.63	11.18	413.33	165.33	13.53
I_7M_2	20.36	44.58	72.33	443.73	32.33	56.11	10.98	379.33	156.85	7.70
SEM±		0.40	0.44	20.05	1.30	0.68	0.26	6.27	2.09	0.22
CD (0.05)		1.20	1.28	NS	NS	NS	NS	18.24	6.09	0.65

poor aeration causes root injury and reduces the inherent capacily of roots to extract water and mineral nutrient from soil, probably due to the accumulation of excess amount of CO_2, and adversely affecting the growth and development of plants. Similar observation was also reported by in broccoli in 2009 [3].

In case of mulching, significantly higher plant height (47.51 cm), wiser plant spread (76.52 cm), maximum leaf area (487.89 cm^2) and stem diameter (36.70 mm) were recorded under black polyethylene mulch compared to traditional practice of unmulched condition (44.32 cm, 72.67 cm, 402.84 cm^2 and 30.71 mm, respectively). Increase in growth due to the use of black plastic mulch might be due to the reduced nutrient losses, weed control and improved hydrothermal regimes of soil, which ultimately helps in increasing growth parameters of the plants [1]. Interaction between mulching and irrigation levels was also found to be significant for plant height and plant spread in this study. Table 1 shows that tallest broccoli plants (49.33 cm) with widest spread of plants 79.50 cm were

measured in treatment combination of 100% PE replenishment daily with black plastic mulch and were both statistically similar with I_2M_2 (48.64 cm and 78.67 cm, respectively). While, the least plant height (40.56 cm) and plant spread (68.89 cm) was measured in surface irrigation with unmulched condition (I_7M_1). Increase in plant height and plant spread due to interactive effect of black plastic mulch and higher soil moisture levels might attributed to the suitable environment conditions [4].

Maturity

Head initiation of broccoli was significantly influenced by both the factors irrigation levels and mulch materials, while their interaction was found to be non significant. Amongst the different irrigation levels, the earliest head initiation (54.23 days) was observed in I_6 (60% PE replenishment at alternate day) and was at par with I_5 (54.72 days) and I_4 (55.42 days). While, the maximum days taken to head initiation was observed in case of surface irrigation (58.14 days) and was at par with 100% PE replenishment both at daily (57.25 days) and alternated day (56.77 days). Increasing the amount of water applied through drip form 60% (54.72 days) to 100% (57.25 days) PE replenishment daily significantly delay the head initiation. Plant that received less or under moisture showed the earlyness and began early initiation of head. The delay in head initiation due to higher soil moisture could be attributed to increase in vegetative growth at higher soil moisture range and thus thereby delaying the harvesting phase. On the other hand, maximum days taken to head initiation were taken by surface irrigation as uneven supply of irrigation water delays the head initiation [5]. Use of black polyethylene mulch in broccoli advance the head initiation by 4.43 days. Early head initiation of broccoli under black polyethylene was attributed to early growth and development due to higher soil temperature, better soil microclimate [6].

Yield and yield attributes

The performance of broccoli plants was significantly affected by both the factors studied (Table 1). Diameter of head, net head weight and yield was found significantly higher at higher irrigation level. Amongst the irrigation levels, 18.79% increase in diameter of head, 29.45% increase in average net head weight and 27.11% increase in yield was obtained in 100% PE replenishment daily compared to surface irrigation (10.58 cm, 343.00 g and 139.76 q ha^{-1}, respectively). The total yield of broccoli decreased significantly with reduction in irrigation levels. Daily irrigation was found to be significantly better over alternate day except irrigation at 60% of PE replenishment in which daily and alernate irrigation was statistically similar. The higher yield and yield attributes at higher irrigation levels could be attributed to adequate supply of moisture which promotes higher uptake of mutrients and ultimately enhancing photosynthesis activity, thereby increased the translocation of photosynthates to storage organ of broccoli. Significantly more diameter of head (12.04 cm), average net head weight (445.43 g), and yield (178.90 q ha^{-1}) were recorded under black polyethylene mulch could be attributed to its favorable moisture conserving capacity in soil, the absorbed nutrients might have been utilized by the heads as a result of which there was increase diameter of head, net head weight and yield. Similar finding were also reported in brinjal [7]. Interaction between irrigation levels and mulch with respect to net head weight and yield was also observed to be significant. Statistically maximum net head weight (501.33 g) and yield (200.53 q ha^{-1}) was observed in black plastic mulch with higher irrigation level daily followed by I_2M_2 (489.33 g and 195.73 q ha^{-1}). While, minimum net head weight (306.67 g) and yield (122.67 q ha^{-1}) was observed in surface irrigation under bare field condition. The cumulative effect of black polyethylene mulch and higher irrigation levels expressed as higher average net head weight and yield due to higher value of moisture level during growth phase under plastic mulching as both the factors favor growth and development in broccoli as described above [8].

Water use efficiency (WUE)

The water use efficiency was significantly influenced by both the factors and their interaction studied (Table 1). It was measured maximum in 60% PE replenishment daily (12.35 q ha^{-1} cm^{-1}) and minimum in surface irrigation (6.86 q ha^{-1} cm^{-1}) i.e. 80.03 60% higher.

Table 2. Economic return of broccoli under different irrigation levels and black polyethylene mulch.

Treatments	Cost of cultivation`/ha			Gross return `/ha			Net return `/ha			B:C ratio		
Irrigation	Mulching material			Mulching material			Mulching material			Mulching material		
levels	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean	M_2	M_2	Mean
P_1	74349.89	85825.89	80087.89	232005	300795	266400	157655	214969	186312	3.12	3.50	3.31
P_2	74205.89	85681.89	79943.89	224805	293595	259200	150599	207913	179256	3.03	3.43	3.23
P_3	73616.64	84868.64	79242.64	220800	278400	249600	147183	193531	170357	3.00	3.28	3.14
P_4	73440.64	84644.64	79042.64	211995	267195	239595	138554	182550	160552	2.89	3.16	3.02
P_5	72643.39	83895.39	78269.39	197595	255195	226395	124952	171300	148126	2.72	3.04	2.88
P_6	72563.39	83751.39	78157.39	193605	247995	220800	121042	164244	142643	2.67	2.96	2.81
P_7	72716.25	75201.75	73959	184005	235275	209640	111289	160073	135681	2.53	3.13	2.83
Mean	73362.3	83409.94		209259	268350		135896	184940		2.85	3.21	

Increase in irrigation water amount reduces the water use efficiency, while the non significant influence was observed amongst the daily and alternate day irrigation. The increased WUE under drip irrigation is because drip system provides precise and measured quantity of water to every individual plant as per requirement. The saving of water combined with higher yield under drip irrigation are the reasons for increased WUE. Surface irrigated plants showed low WUE, because the increased amount of water applied did not result in corresponding increase in yield. Similar findings were also observed in tomato [9]. As far as water use efficiency under mulching is considered, it was black polyethylene that gave significantly higher water use efficiency (10.99 q ha^{-1} cm^{-1}) as the role of mulches in increasing the yield and water conservation is well known. The cumulative effect of black polyethylene mulch and lower irrigation levels expressed as higher WUE due to higher saving of water combined with higher yield by both the factors as described above.

Economic analysis

Use of black plastic mulch during the study proved to be better than that unmulched condition in achieving higher gross return of Rs 268,350.00 ha^{-1} along with maximum net return of 18490.00 ha^{-1} and benefit - cost ratio 3.21 compared to unmulched in which the benefit cost ratio is 2.85. Out of irrigation levels, the highest gross return (Rs 266,400.00 ha^{-1}), net profit (Rs 186,312.00 ha^{-1}) and benefit - cost ratio (3.31) was obtained with 100% PE replenishment daily. However, minimum gross return Rs 209,640.00 ha^{-1}, net return of Rs 135,681.00 ha^{-1} was obtained from surface irrigation. While, minimum cost- benefit ratio of 2.81 was obtained from 60% PE replenishment at alternate day. Among the different treatment combinations, I_1M_2 (100% PE replenishment daily and black plastic mulch) proved better over all other treatment combinations in terms of achieving higher gross and net return with cost benefit ratio i.e. Rs 300,795.00 ha^{-1}, Rs 214,969.00 ha^{-1} and 3.50, respectively. Minimum net return and benefit-cost ratio of Rs 111,289.00 ha^{-1} and 2.53 respectively, were recorded in traditional practices. The increased net return and higher benefit-cost ratio under black polyethylene mulch were attributed to higher yield, fewer requirements of resources and better management practices resulting in higher economic return to the grower [1, 10].

Based on the of present investigation, it could be concluded that in order to harvest maximum return form broccoli, it should be grown using black plastic mulch and irrigated at 100% PE replenishment daily through drip system.

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