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Drip irrigation and fertigation requirement of broccoli under mid hill conditions

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Abstract

Water conserving irrigation technologies are used now a days for economic and environmental sustainability of commercial agriculture. An experiment was laid in randomized block design to find out the effect of irrigation methods and fertigation levels on broccoli (*Brassica oleracea* var. italica L.) production during 2016-18. The treatments comprised drip irrigation at three levels, viz. 100, 80 and 60% of the ET_c (i.e. DI100, DI80 and DI60) in conjunction with fertigation of 100, 85 and 70% of recommended dose of fertilizers with black polyethylene mulch. Surface irrigation with basal application of recommended dose of fertilizers without mulch was taken as a control. The study indicated that irrigation methods manipulated the moisture content of the soil comprehensively and soil moisture was near to the field capacity throughout the growth period in DI100 and DI80 with mulch, whereas, in conventional surface irrigation, the soil moisture status varied from field capacity to deficient status. Plant height, days to marketable head, weight of central and secondary heads, available NPK, leaf NPK content and total yield were observed to be significantly affected by irrigation methods and levels of fertigation. Water use efficiency varied from 4.95 q/ha/cm under surface irrigation to 27.95 q/ha/cm under best treatment of drip irrigation. Highest benefit cost ratio (2.63) was recorded with the treatment combination of drip irrigation @ 60 % ETc with 70 % recommended dose of fertilizer through fertigation.

Key words: Broccoli, Drip irrigation, Fertigation, Water Use Efficiency, Fertilizer Use Efficiency

Introduction

Sprouting broccoli (*Brassica oleracea* var. italica L.) belongs to family Brassicaceae commonly known as mustard family. Broccoli is an Italian word derived from Brachium, meaning an arm of branch (Chaudhary 1970). It is an important winter season vegetable crop, which resembles cauliflower. Most varieties are grown in temperate region, even in sub-arctic climate (Rubatzky and Yamaguchi 1997). Broccoli is a rich source of Vitamin- A, E, C along with fibres. The availability of â-carotene in broccoli is 22-24 % higher in comparison to fatty foods thereby enhances the carotenoid uptake by the human body. There is tremendous scope of increasing area as well as production in Himachal Pradesh as broccoli grown here becomes off season vegetable in the plains of North India fetching very remunerative price to the farmers. But the potential for offseason vegetable cultivation has not been harnessed fully owing to irrigation constraints. Moreover, conventional irrigation methods are not feasible due to mountainous terrains. Some parts of Himachal Pradesh receive annual rainfall as high as 3000 mm with average rainfall being 1200 mm but about 85 per cent of it occurs during June to September and most of monsoon rainfall goes waste as runoff due to uneven terrain of the region. The months of October, November and December are generally dry, due to which rabi crops including broccoli, fail frequently and yield levels are very low. Under such circumstances rainwater harvesting and application of harvested water by micro irrigation system (sprinkler or drip irrigation) is the most feasible option. Further, use of water conserving techniques as polyethylene mulch can help in conserving the moisture for maximizing benefits (Spehia et al. 2013). Drip irrigation not only saves water but also improve fertilizer use efficiency by allowing water containing fertilizers to drip slowly on the surface of soil near to the plant roots or directly to the root zone, through a network of valves, pipes, tubing and emitters. This system maintains the moisture throughout the planting area for a longer period as compared to conventional method of irrigation. It is eco-friendly irrigation system which not only saves precious irrigation water but also increases productivity to the tune of 30-40 % over traditional methods of irrigation.

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The optimum utilization of water, fertilizers and soil resources is of utmost importance for sustainability of any production system. Broccoli is a heavy feeder crop and requires considerable amount of N, P and K which are applied through basal application by the farmers. This leads to wastage of costly input through leaching, volatilization and uptake by the weeds. Therefore, more efficient method of fertilization is needed that can help in maximum uptake of applied fertilizers by the crop only. Since broccoli is an emerging cash crop for farmers of Himachal Pradesh, the standardization of irrigation schedule and fertigation doses shall help in standardizing water to applied and reducing the cost of fertilizers and labour besides increasing yield and quality. Irrigation and fertigation are also effective in cold desert regions also where water and nutrients can be applied judiciously with available water through drip irrigation.

Materials and Methods

The experiment was conducted for two consecutive years during 2016-17 and 2017-18 in the research experimental farm of the Precision Farming Development Centre, Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). It is situated at 30° 52' North Latitude and 77° 11' East longitude at an elevation of 1260 m above mean sea level having average slope of 7-8 % and represent the mid hill zone of Himachal Pradesh with 1115 mm average annual rainfall and about 75 % of it is received during the monsoon period (mid- June to mid-September). NP and K status of experimental soil was taken before the experiment (Table 1). The broccoli cv. Palam Samridhi was transplanted at 60×45 cm spacing in 1.8 1 m plot size. Treatments included 3 irrigation levels (100, 80 and 60% of crop evapotranspiration (Etc)) with 3 fertigation levels: 100, 85 and 70% of recommended dose (RD) of conventional fertilizers. Surface irrigation + conventional application of fertilizers (Conventional Practices) was taken as control. The treatments were combined as T_1: Drip irrigation equal to100% ETc + Drip fertigation with water soluble fertilizers @ 100% RD of conventional fertilizers; T_2: Drip irrigation equal to 100% ETc + Drip fertigation with water soluble fertilizers @ 85% RD of conventional fertilizers; T_3: Drip irrigation equal to 100% ETc + Drip fertigation with water soluble fertilizers @ 70% RD of conventional fertilizers; T_4: Drip irrigation equal to 80% ETc + Drip fertigation with water soluble fertilizers @ 100% RD of conventional fertilizers, T_5: Drip irrigation equal to 80% ETc + Drip fertigation with water soluble fertilizers @ 85% RD of conventional fertilizers; T_6: Drip irrigation equal to 80% ETc + Drip fertigation with water soluble fertilizers @ 70% RD of conventional fertilizers, T_7: Drip irrigation equal to 60% ETc + Drip fertigation with water soluble fertilizers @ 100% RD of conventional fertilizers; T_8: Drip irrigation equal to 60% ETc + Drip fertigation with water soluble fertilizers @ 85% RD of conventional fertilizers; T_9: Drip irrigation equal to 60% ETc + Drip fertigation with water soluble fertilizers @ 70% RD of conventional fertilizers and T_{10}: Surface irrigation + conventional application of fertilizers (Control). All the treatments, except for treatment $T_{10,}$ were applied with black polyethylene mulch (30 thickness). Results were statistically analysed by using Randomized Block Design with 3 replications as per Panse and Sukhatme (2000).

Table 1: Physio-chemical properties of experimental soil before the start of experiment

Properties	Values
Soil pH	6.52
EC(dSm^{-1})	0.28
Organic Carbon (%)	1.00
Available N (kg ha^{-1})	260.5
Available P (kg ha^{-1})	48.5
Available K (kg ha^{-1})	345.3

Results and Discussion

The plant growth is a function of cell division and cell enlargement, which depends upon availability of inputs like nutrients and water. Plant height (Table 2) was recorded to be maximum (54.76 cm) under the treatment T_4 and minimum (43.82 cm) under T_{10}. The quantitative increase in plant height observed in treatment I_2F_1 might be due to the fact that the soil was kept near to the field capacity throughout the crop growth period in the active root zone, resulting in low suction which facilitated better water and nutrient uptake by the plants and also greater turgidity of cells with increase in available soil moisture leading to quicker cell division and enlargement. Thentu et al. (2016) recorded higher plant height with drip irrigation at 0.8 ETc in broccoli. Araki and Yamaguchi (2007) and Salunkhe et al. (2015) concluded that drip

Table 2: Effect of different level of irrigation and fertigation on plant height and yield contributing traits in broccoli

Treatments	Plant height (cm)	Wt. of central head (g)	Wt. of secondary heads per plant (g)	Total yield (q/ha)
T_1	51.56	493.33	208.83	234.05
T_2	51.97	490.67	206.00	232.22
T_3	52.48	510.00	199.33	236.44
T_4	54.76	530.33	217.67	249.67
T_5	52.22	528.67	215.67	248.11
T_6	52.67	525.00	209.80	244.66
T_7	52.11	525.33	214.33	246.55
T_8	52.64	522.00	211.00	244.33
T_9	52.22	518.33	215.00	244.75
T_{10}	43.82	319.33	126.00	148.44
$CD_{0.05}$	3.42	8.78	7.95	4.64

fertigation was equally efficient in improving growth parameters with a 30 % saving in fertilizer compared with the conventional system of fertilizer application. Similar findings have also been reported by Xu and Leskovar (2014), Mannan and Haque (2000) in cabbage and Luvai et al. (2014) in tomato.

Weight of central head (Table 2) was recorded to be highest (530.33 g) in treatment T_4 which was at par with T_5, T_6, T_7 and T_8 and was observed to be lowest (319.33 g) under T_{10}. Maximum (217.67 g) weight of secondary heads per plant was found under treatment T_4 which was statistically at par with T_5, T_6, T_7 and T_8 and minimum (126.00 g) was found to be in $T_{10.}$ The results support the findings by Ayas et al. (2011) who reported maximum head weight in broccoli with K_2Cp (0.75 coefficient of pan evaporation treatment) which is in concurrence with this study. These results also correspond to the findings of Singh et al. (2011) and Chaurasiya and Sahu (2015) who reported maximum fruits under drip irrigation in combination with fertigation.

Total yield (Table 2) was recorded to be highest (249.67 q/ha) in T_4 which was a par with T_5 and T_7 while, lowest (148.44 q/ha) was under T_{10} (Table 1). Present findings are in line with the findings of Jeelani et al. (2017) and Kumari et al. (2018). They reported that irrigation at 80 % CPE (Cumulative Pan Evaporation) with 100 per cent fertigation recorded highest yield compared to the treatment with irrigation at 60 and 40 per cent CPE and application of 100 per cent fertilizers through conventional method. Similar experiment conducted by Kumari et al. (2018) also revealed that drip irrigation at 80% of ETc gave significantly higher yield compared with the 60% of ETc. The reasons for optimum yield in broccoli with 80 % of ETc were that that at this soil moisture content, the crop was neither deficient in its water requirement nor incurred more expenditure like in 100 % of ETc. The soil was kept near to field capacity resulted in low suction throughout the growing period in the root zone of broccoli and the marked reduction in curd yield in drip irrigation at 0.6. ETc was particularly due to water stress which were not fulfil the crop water requirement. Fertigation at 100% RD of fertilizers yielded maximum. Brahma et al. (2010) and Biradar et al. (2018) supported the findings under open field conditions and net house conditions, respectively.

Minimum (8.82 cm) water was applied in the treatment T_7, T_8 and T_9 followed by $T_{4,}$ $T_{5,}$ T_6 and T_1, T_2 and T_3 and maximum (30 cm) was under T_{10} (Table 3). Water use efficiency was recorded maximum (27.95 q/ha/cm) in T_7 while, minimum (4.95 q/ha/cm) was in T_{10}. The increased WUE under drip irrigation is due to precise

Table 3: Total Water applied (cm) and water use efficiency (q/ha/cm) under different level of irrigation and fertigation

Treatments	Total Water applied (cm)	Water-use-efficiency (q/ha/cm)
T_1	14.71	15.91
T_2	14.71	15.79
T_3	14.71	16.07
T_4	11.76	21.23
T_5	11.76	21.10
T_6	11.76	20.80
T_7	8.82	27.95
T_8	8.82	27.70
T_9	8.82	27.71
T_{10}	30	4.95

and direct application of water to the root zone without wetting the entire area, consequently leading to lesser evaporative and downward losses of water compared to surface irrigation. Other possible reason might be the availability of nutrients and soil moisture at low tensions with reduced surface evaporation, leading to increased yields. The same results were reported by Tiwari et al. (2003) and Abdul et al. (2014) for cabbage crop. These results were in confirmation with the results of Thentu et al. (2016). They also reported that drip irrigation at 0.6 ETc registered maximum water use efficiency.

The Available N, P and K content before the start of the experiment in the soil was 260.5, 48.5 and 345.3 Kg/ ha, respectively whereas, after conclusion of the experiment available N, P and K content in the soil was recorded maximum 345.61, 103.39 and 455.87 kg/ha, respectively, under treatment T_4 while, minimum NP and K content (331.27, 95.50 and 432.66 q/ha/cm) was observed in the treatment T_{10} (Table 4) depicting that the fertigation treatments had significant effect on the available nutrient content in the soil. Under drip irrigation moisture content was noticed to be high in upper soil layers owing to its application in small quantity and at frequent intervals, which ultimately led to higher concentration of available N P and K as compared to

Table 4: Effect of different level of irrigation and fertigation on available N, P & K (kg/ha) in soil after the harvest of crop

Treatments	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1	343.11	101.11	452.67
T_2	342.74	100.82	452.22
T_3	342.17	100.26	451.81
T_4	345.61	103.39	455.87
T_5	344.88	102.79	454.38
T_6	344.21	102.40	453.83
T_7	345.34	102.78	455.58
T_8	344.79	102.37	454.27
T_9	344.35	102.14	453.74
T_{10}	331.27	95.50	432.66
$CD_{0.05}$	2.32	1.87	2.11

surface irrigation where less frequent and heavy volume of water application in each irrigation resulted in higher downward movement of applied nutrients. Similar findings have been reported by Sharma et al. (2012) and Patil and Das (2015).

Leaf nutrient N, P and K content was observed to be highest (2.77, 0.43 and 1.95 %, respectively) under T_4 treatment whereas, lowest (1.58, 0.28 and 1.63 %, respectively) leaf nutrient N,P and K content was found in the T_{10} treatment (Table 5). Preferential uptake of water from the sufficiently moist soil promoted the movement of nutrient ions towards roots and their uptake. Furthermore, application of polyethylene mulch significantly increased the leaf nutrient content over unmulched treatment, which may be ascribed to more favourable hydrothermal conditions, thereby resulting in better uptake of nutrients. The higher uptake of phosphorus in treatment I_2F_1 also might be due to the fact that nitrogen increases the cation exchange capacity of plant roots and these make them more efficient in absorbing other nutrient ions like phosphorus and potassium. The increased nutrient content in leaf may also be due to split application of N and K under drip fertigation that resulted in minimal loss of nutrients thereby making them available continuously to the crop. These results are in line with the findings of Panwar et al. (2007) in mango; Savitha et al. (2010) in onion and Ugade et al. (2014) in brinjal.

Fertilizer use efficiency was influenced by different treatments and the highest fertilizer use efficiency of 73.97 kg/kg of nutrient was observed in treatment T_7 while lowest fertilizer use efficiency (0.72 kg/kg of nutrient) was observed in conventional practice (Table 6). The higher FUE in this treatment might be due to efficient use of nutrients at various stages of crop growth and practically no leaching of nutrients in the form of runoff. The lower fertilizer use efficiency in conventional practice may be due to non-uniform distribution and inadequate availability of nutrients in the root zone of a crop. The results are in conformity with the findings of Gupta et al. (2009) in broccoli and Veeranna et al. (2001) in chilli.

Table 5: Effect of different level of irrigation and fertigation on N, P and K content (%) in leaf

Treatments	N (%)	P (%)	K (%)
T_1	1.98	0.35	1.81
T_2	1.81	0.32	1.78
T_3	1.74	0.31	1.70
T_4	2.77	0.43	1.95
T_5	2.74	0.42	1.93
T_6	2.68	0.41	1.92
T_7	2.64	0.40	1.91
T_8	2.60	0.40	1.92
T_9	2.58	0.41	1.93
T_{10}	1.58	0.28	1.63
$CD_{0.05}$	0.20	0.03	0.04

Table 6: Total fertilizer applied (kg) and fertilizer use efficiency (kg/kg) under different level of irrigation and fertigation

Treatment	Total fertilizer applied (kg)	Fertilizer-use-efficiency (kg/kg)
T_1	461.00	50.77
T_2	461.00	50.37
T_3	461.00	51.29
T_4	388.80	64.22
T_5	388.80	63.81
T_6	388.80	62.93
T_7	333.30	73.97
T_8	333.30	73.31
T_9	333.30	73.34
T_{10}	20699.00	0.72

Table 7: Effect of different level of irrigation and fertigation on economics of treatments

Treatments	Yield (q/ha)	Gross Income (Rs/ha)	Total cost of cultivation (Rs/ha)	Net Returns (Rs/ha)	B:C Ratio
T_1	234.05	351075	120116.31	230958.69	1.92
T_2	232.22	348330	110642.18	237687.82	2.15
T_3	236.44	354660	101170.10	253489.90	2.51
T_4	249.67	374505	120116.31	254388.69	2.12
T_5	248.11	372165	110642.18	261522.82	2.36
T_6	244.66	366990	101170.10	265819.90	2.63
T_7	246.55	369825	120116.31	249708.69	2.08
T_8	244.33	366495	110642.18	255852.82	2.31
T_9	244.75	367125	101170.10	265954.90	2.63
T_{10}	148.44	222660	68363.62	154296.38	2.26

▪ Sale price of broccoli : Rs 15/kg

Maximum B:C ratio (2.63:1) was observed in treatment T_6 and T_9 whereas, minimum B:C ratio of 1.92:1 was observed in treatment T_1 (Table 7). Treatment T_4 recorded maximum gross income due to increased yield while maximum net income was recorded under treatment T_9 as the cost of cultivation was significantly lower than treatment T_4 but the yield difference was very low and this trend is mirrored in the B:C ratio. The B:C ratio in treatment T_{10} was higher than many treatments as the cost of cultivation was very less due to non-installation of drip system and mulch.

Conclusion

Maximum growth and yield were obtained under drip irrigation @ 80% ETc in conjunction with black polyethylene mulch (30 hickness) but was at par with irrigation @ 60% ETc in conjunction with black polyethylene mulch. The total water requirement under 80% ETc was 11.76 cm, whereas, under 60% ETc irrigation water requirement was 8.82 cm. Fertigation with water soluble fertilizers @ 100% RDF gave best results pertaining to uptake and corresponding yield. Benefit: cost ratio was recorded highest under 60% ETc at 100% RDF but was at par with 60% ETc @ 70% RDF. Therefore, it can be concluded that broccoli crop can be beneficially grown with 70% of recommended dose of fertilizer when irrigated at 60% of ETc through drip irrigation in conjunction with black polyethylene mulch.

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व्यवसायिक खेती की आर्थिक एवं पर्यावरणीय स्थिरता के लिए जल संरक्षण को बढ़ावा देने वाली सिंचाई तकनीकों का उपयोग किया जा रहा है। इसी के अंतर्गत विभिन्न सिंचाई तथा फर्टिगेशन स्तरों का ब्रोकली के उत्पादन पर प्रभाव जानने के लिए वर्ष 2016–2018 तक एक शोध किया गया। इसमें वाष्पीकरण पर आधारित सिंचाई के तीन स्तरों 100 प्रतिशत (डीआई 100), 80 प्रतिशत (डीआई 80) तथा 60 प्रतिशत (डीआई 60) को रसायनिक खादों के 100 प्रतिशत अनुमोदित स्तर के बराबर (100 प्रतिशत), 80 प्रतिशत तथा 75 प्रतिशत स्तर के साथ देखा गया। सभी उपचारों में काली पालीथीन पलवार (मल्च) का उपयोग किया गया। सतही सिंचाई वाली उपचार में पारंपरिक तरीके से खाद डाली गयी जिसे नियंत्रतक के रूप में रखा गया। शोध स्पष्ट हुआ की सिंचाई के तरीके मिट्टी में नमी को बहुत हद तक प्रभावित करते हैं तथा डीआई 100 एवं डीआई 80 में नमी प्रक्षेत्र क्षमता के आस–पास रही वहीं सतहीं सिंचाई में नमी प्रक्षेत्र क्षमता से लेकर बहुत कम तक मापी गयी। इसी तरह पौधे की लम्बाई, कुल उपलब्ध नत्रजन, फास्फोरस तथा पोटैशियम पत्तियों में नत्रजन, फास्फोरस तथा पोटैशियम की मात्रा तथा ब्रोकली का कुल उत्पादन भी सिंचाई तथा फर्टिगेशन के स्तर से प्रभावित पायी गयी। सबसे अच्छी उपचार में जल उपयोग दक्षता 27.95 कुन्तल प्रति हेक्टेयर प्रति सेन्टी मीटर पायी गयी जबकि सतही सिंचाई वाली उपचार में यह 4.95 कुन्तल प्रति हेक्टेयर प्रति सेन्टी मीटर पायी गयी। सबसे उपयुक्त लाभः व्यय अनुपात (2.63) 60 प्रतिशत टपक सिंचाई + 70 प्रतिशत अनुमोदित खाद वाली उपचार पायी गयी।

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