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Growth attributes of broccoli (*Brassica oleracea* var. *italica*) as influenced by different irrigation levels and fertigation

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Abstract
Drip irrigation and fertigation with different levels studied in broccoli (*Brassica oleracea* var. *italica*) to evaluate the effect on growth parameters. The experiment was laid out in randomized block design with factorial concept and nine treatment combinations comprising of three levels of drip irrigation (I_1: 1.0 PEF, I_2: 0.8 PEF and I_3: 0.6 PEF) and three levels of fertigation (F_1: 100% RDF, F_2: 80% RDF and F_3: 60% RDF) with four replications. The results revealed that growth parameters i.e. number of leaves, fresh and dry matter accumulation plant^{-1}, LAI at 45 DATP, days to curd initiation and days to harvesting of curd as influenced by different treatments. Number of leaves, fresh and dry matter accumulation plant^{-1} and LAI at 45 DATP found significantly higher under drip irrigation at 1.0 PEF (I_1) and fertigation with 100% RDF (F_1) while least days to curd initiation and harvesting of marketable curd were noted under drip irrigation at 0.6 PEF and fertigation at 60% RDF.

Keywords: Broccoli, fertigation, drip irrigation, PEF

Introduction
Broccoli (*Brassica oleracea* var. *italica*) is a member of cole group crop and a close relative of cabbage, cauliflower, kale, knol-khol, Brussels sprouts, collards and bok choy. The word broccoli comes from the Latin brachium and Italian brocco meaning 'arm' or 'branch' (Choudhury, 1970) [3]. It can be distinguished from cauliflower by having a head composed of differentiated flower bud rather than head. Its edible portion consists of immature, fully differentiated flower buds and tender portions of the upper stem (Kohli *et al*., 2006) [8].
In drip irrigation, water is applied drop by drop on continuous basis through closed network of plastic pipes at frequent intervals near to the root zone for consumptive use of the crop. High-frequency water management by drip irrigation provides daily requirement of water to a portion of the root zone of each plant and sometimes maintains a high soil matric potential in the rhizo-sphere to reduce plant water stress (Nakayama and Bucks 1986) [10]. The regulated supply of water through drippers not only affects the plant root and shoot growth, but also the nutrients uptake. It minimizes conventional losses of water by deep percolation, evaporation and runoff. The added advantage of drip system is that water soluble fertilizers can also be applied through this system and the process is known as fertigation. With the advent of this new method of irrigation system, traditional method of fertilization which is still practiced by the farmers is being slowly replaced by fertigation.

Materials and Methods
Location and soil of experimental site
A field experiment was carried out at Soil and Water Management Research Farm, Navsari, Soil and Water Management Research Farm, Soil and Water Management Research Unit, Navsari Agriculture University, Navsari is located in Gujarat during *rabi* season of 2019-20. The soils of experimental unit was clayey in texture, alkaline in nature with normal electrical conductivity, low in organic carbon and available nitrogen, medium in available phosphorus and fairly high in available potassium.

Climatic conditions
Agro-climatically, Soil and Water Management Research Farm falls under South Gujarat heavy rainfall zone-1 (Agro-ecological situation-3) of Gujarat. The climate of this region is characterized by fairly hot summer, moderately cold winter and warm humid monsoon with

heavy rainfall. In general, monsoon commences from the third week of June and ends up to last week of September. Pre-monsoon rains in the first week of June and post monsoon rains in the month of October-November are not uncommon. The winter season sets in usually by the first week of November and continues till the middle of February. December and January are the coldest months of winter. Usually the summer season commences during the middle of February and ends by the middle of June. The temperature is increasing from February and reaches the maximum in the month of April or May.

Treatment details

The experiment was laid out in randomized block design with factorial concept and nine treatment combinations comprising of three levels of drip irrigation (I_1: 1.0 PEF, I_2: 0.8 PEF and I_3: 0.6 PEF) and three levels of fertigation (F_1: 100% RDF, F_2: 80% RDF and F_3: 60% RDF) with four replications.

The seeds of cultivar TSX-0788 of broccoli were used in the present investigation which has a maturity of 60-65 days. It has an excellent dome with compact head with dark green beads. Plant having medium-low size and its thick stem makes good weight of products (head). The crop was fertilized with NPK as per treatment allotted to each treatment. A fertilizer dose of 120-60-00 kg NPK ha^{-1} was applied to all the treatments in form of 17-44-00% NPK (Urea phosphate) water soluble fertilizer and remaining N in the form of Urea, through drip at weekly interval in 6 equal splits starting from one week after transplanting of broccoli. The first common irrigation of 80 mm depth was applied immediately after transplanting by flooding for better establishment of seedlings at initial stage of crop and rest of required quantity of water was applied through drip irrigation at alternate day on the basis of pan evaporation.

Observations recorded

For all the growth parameters i.e. number of leaves, fresh and dry matter accumulation $plant^{-1}$, LAI at 45 DATP, previously selected five plants from each net plot was selected and observations recorded at 45 DATP. The mean number was worked out and noted for each treatment. All the plants from net plot were visually observed from transplanting to curd initiation and transplanting to curd harvesting in all the treatments. The number of days required to initiation and curd harvesting were recorded by counting actual number of days and registered for each treatment accordingly.

Results and Discussion

Data on the growth parameters i.e. number of leaves, fresh and dry matter accumulation $plant^{-1}$, LAI at 45 DATP, days to curd initiation and days to harvesting of curd as influenced by different treatments have been described in Table 1 to 2.

Irrigation levels

An examination of data revealed that different irrigation levels significantly influenced on number of leaves, fresh and dry matter accumulation $plant^{-1}$and LAI at 45 DATP during 2019-20, 2020-21 and in pooled analysis (Table 1 and 2). Drip irrigation level at 1.0 PEF (I_1) recorded significantly higher number of leaves, fresh and dry matter accumulation $plant^{-1}$ and LAI at 45 DATP during both the years and in pooled results. Further, fresh and dry matter accumulation $plant^{-1}$ found at par with treatment I_2 (drip irrigation level at 0.8 PEF) during both the years of study and in pooled results but, in case of number leaves and LAI, were at par with drip irrigation level at 0.8 PEF (I_2) during both years of investigation. The reason of increase in growth attributes might be due to higher level of irrigation through drip system improved the avaibility of water around the rhizosphere and better utilization and uptake by plants and also increase the avaibility of nutrients throughout the crop growth period which effects on plant growth and ultimately increase leaves per plant, fresh and dry matter accumulation $plant^{-1}$and LAI at 45 DATP. The results are in conformity with the findings of Thentu *et al.* (2016) [12] in broccoli and Kumar and Sahu (2013) [9] and Sinha and Narzary (2016) [11] in cabbage crop for number of leaves, by Erden *et al*. (2010) [4] in broccoli and Gupta and Chattoo (2014) [6] in knoll-khol crop for dry matter production and by Thentu *et al.* (2016) [12] and Jeelani *et al.* (2017) [7] for LAI.

A perusal of data presented in Table 2 indicated that various levels of drip irrigation exhibited their significant effect on days to curd initiation and harvesting of curd. Significantly the less days required to curd initiation and harvesting of curd were recorded when crop irrigated through drip at 0.6 PEF (I_3) during both the years of study and in pooled results, respectively in which days to curd initiation remained statistically at par with treatment I_2 (Drip irrigation at 0.8 PEF) during 2019-20 and 2020-21. While, significantly the more days required to curd initiation and harvesting of curd noted when crop was irrigated with drip at 1.0 PEF (I_1) during both the years and in pooled results, respectively. At lower level of drip irrigation, curd initiation and harvesting days earlier might be due to moisture deficit condition arises and plants attain reproductive stage forcefully. While, delayed in curd initiation and harvesting days with higher level of drip irrigation might be due to more water supply through irrigation prolong the vegetative period of crop and initiation of curd enhanced and delayed the harvesting of crop. The results are in conformity with the findings of Sinha and Narzary (2016) [11] in cabbage and Gadhavi *et al.* (2017) [5] in cauliflower crop.

Fertigation

The data furnished in Table 1 and 2 revealed that fertigation impart their significant effect on number of leaves, fresh and dry matter accumulation $plant^{-1}$and LAI at 45 DATP during 2019-20, 2020-21 and in pooled results. Fertigation at 100% RDF (F_1) observed significantaly higher number of leaves, fresh and dry matter accumulation $plant^{-1}$ and LAI at 45 DATP during both years and in pooled results. However, fresh and dry matter accumulation $plant^{-1}$ found at par with fertigation level of 80% RDF (F_2) during both the years of study and in pooled results but, in case of number leaves and LAI, were at par with 80% RDF through fertigation (F_2) during both years of investigation. Fertigation steadily supply nutrients directly to the root zone of crop at different growth stages as per requirement of crop and more uptake of nutrients by plants and thereby increasing the cell activities which ultimately contributed to produce more number of leaves per plant, fresh and dry matter accumulation $plant^{-1}$ and LAI at 45 DATP. These results are supported by Brahma *et al.* (2010) [2] in broccoli and Kumar and Sahu (2013) [9] and Sinha and Narzary (2016) [11] in cabbage crop for number of leaves, by Ayas (2021) [1] in cabbage and Gupta and Chattoo (2014) [6] in knol-khol crop for dry matter production and by Jeelani *et al.*

(2017) [7] for LAI.

The results furnished in Table 2 clearly indicated that different fertigation levels exerted their significant effect on days to curd initiation and harvesting of curd. Application of 60% RDF through fertigation (F_3) were taken significantly least days to curd initiation and harvesting of curds during both the years of study and in pooled results. However, days to curd initiation remained statistically at par with treatment of 80% RDF through fertigation (F_2) during both the years of study, but in case of days to harvesting it was at par in 2nd year only. However, significantly more days were taken for curd initiation and harvesting when crop fertilized with maximum supplied of the fertilizer *i.e.* 100% RDF (F_1) through fertigation during individual years as well as in pooled results. This result might be due to the fact that higher level of fertigation provides more nutrients which enhance vegetative phase and delayed reproductive phase, while lower dose of fertigation hasten vegetative phase which moves to early reproductive phase. These results are supported by Sinha and Narzary (2016) [11] in cabbage and Gadhavi *et al.* (2017) [5] in cauliflower crop.

Table 1: Number of leaves and fresh and dry matter accumulation at 45 DATP as influenced by different irrigation levels and fertigation

Treatments	No. of leaves			Fresh and dry matter accumulation (g plant^{-1})					
				2019-20		2020-21		Pooled	
	2019-20	2020-21	Pooled	Fresh	Dry	Fresh	Dry	Fresh	Dry
(A) Irrigation levels (I)									
I_1: 1.0 PEF	14.2	14.3	14.2	235.19	22.34	236.44	22.92	235.82	22.63
I_2: 0.8 PEF	13.4	13.5	13.5	224.32	20.99	224.82	21.22	224.57	21.10
I_3: 0.6 PEF	11.9	12.0	12.0	184.39	15.37	185.81	16.16	185.10	15.76
S.Em±	0.34	0.32	0.23	6.34	0.71	5.23	0.82	4.11	0.54
CD (P=0.05)	0.98	0.95	0.66	18.50	2.08	15.25	2.40	11.68	1.55
(B) Fertigation (F)									
F_1: 100% RDF	14.3	14.4	14.3	230.58	21.28	233.08	22.25	231.83	21.76
F_2: 80% RDF	13.3	13.5	13.4	219.21	20.02	221.54	20.99	220.37	20.51
F_3: 60% RDF	11.9	12.0	11.9	194.12	17.40	192.45	17.06	193.29	17.23
S.Em±	0.34	0.32	0.23	6.34	0.71	5.23	0.82	4.11	0.54
CD (P=0.05)	0.98	0.95	0.66	18.50	2.08	15.25	2.40	11.68	1.55
CV%	8.82	8.48	8.65	10.23	12.65	8.39	14.18	9.35	13.46
Significant interaction	-	-	-	-	-	-	-	-	-

Table 2: LAI at 45 DATP, days to curd initiation and harvesting as influenced by different irrigation levels and fertigation

Treatments	LAI			Days to curd initiation			Days to harvesting of curd		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
(A) Irrigation levels (I)									
I_1: 1.0 PEF	2.15	2.16	2.15	53.8	52.2	53.0	76.1	74.2	75.1
I_2: 0.8 PEF	2.05	2.05	2.05	47.3	47.6	47.4	72.2	70.6	71.4
I_3: 0.6 PEF	1.45	1.43	1.44	43.8	43.8	43.8	68.4	67.1	67.8
S.Em±	0.05	0.05	0.03	1.32	1.33	0.94	0.87	1.08	0.70
CD (P=0.05)	0.14	0.13	0.09	3.86	3.87	2.66	2.55	3.16	1.98
(B) Fertigation (F)									
F_1: 100% RDF	2.14	2.13	2.14	54.0	52.1	53.0	75.2	73.6	74.4
F_2: 80% RDF	2.02	2.02	2.02	47.3	47.5	47.4	72.3	70.8	71.5
F_3: 60% RDF	1.49	1.48	1.49	43.6	43.9	43.8	69.3	67.4	68.3
S.Em±	0.05	0.05	0.03	1.32	1.33	0.94	0.87	1.08	0.70
CD (P=0.05)	0.14	0.13	0.09	3.86	3.87	2.66	2.55	3.16	1.98
CV%	9.00	8.33	8.67	9.49	9.60	9.54	4.19	5.31	4.77
Significant interaction	-	-	-	-	-	-	-	-	-

Interaction

Interaction effect of irrigation levels and fertigation did not found any significant difference with respect to all the growth parameters, *viz.;* number of leaves, fresh and dry matter accumulation plant^{-1}, LAI at 45 DATP, days to curd initiation and days to harvesting of curd in first year, second year and in pooled analysis.

Conclusion

From the two year experimentation, it can be concluded that higher growth attributes obtained when crop irrigated with one common surface irrigation at the time of transplanting and rest of the irrigations scheduled through drip at 0.8 PEF at an alternate days along with the application of 80% RDF (96-48-00 kg NPK ha^{-1}) through fertigation in six equal splits at weekly interval started from a week after transplanting of broccoli.

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