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EFFECT OF IRRIGATION REGIMES ON BROCCOLI CULTIVATION IN SOILLESS MEDIA UNDER NATURAL VENTILATED NET-CUM-POLYHOUSE

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ABSTRACT

The experiment was conducted to study the effect of irrigation regimes on broccoli cultivation in soilless media under protected cultivation at Junagadh Agricultural University, Junagadh, Gujarat, India for the period of two year 2020-21 and 2021-22. The irrigation regimes was applied at 0%, 80%, 60% and 40% of actual water requirement. ET_o was calculated by the standard and well accepted FAO-56 method. The yield attribute parameter like stem diameter, plant height, No. of leaves per plant, plant canopy, curd diameter, curd weight and yield was measured. The effect of irrigation regimes on yield and yield attribute were found significantly highest in no regimes (full irrigation) and at par with 80% of regimes except No. of leaves per plant. Crop yield response factor (k_y) was found as 0.962. The highest water use efficiency (WUE) was found 35.17 kg/m^3 for the irrigation regimes at 80% followed by 60% irrigation regime. However, yield is critically reduced if irrigation regimes applied beyond 80%. The irrigation regime up to 80% of crop water requirement in broccoli crop during the scare water resources under natural ventilated net-cum-polyhouse is advisable.

Key words : Broccoli, Crop yield response factor (k_y), Irrigation regimes, Natural ventilated net-cum-polyhouse, Water use efficiency (WUE), Yield attribute parameters.

Introduction

In 1960, the global population stood at 3 billion with a per capita land availability of 0.5 hectares. However, with the current population reaching 6 billion, this allocation has drastically reduced to a mere 0.25 hectares and projections anticipate a further decline to 0.16 hectares by 2050. It has become increasingly apparent that sustaining the entire populace solely through open-field agricultural production is becoming unfeasible (Mamta and Shraddha, 2013; Sengupta and Banerjee, 2012). The cultivation of vegetables, fruits, and flowers faces significant challenges due to unpredictable climatic conditions such as intense precipitation, thunderstorms, heightened solar radiation, temperature fluctuations and varying humidity levels. These variables considerably limit vegetable production in open-field systems (Max *et al.*, 2009), often resulting in complete crop losses due to uncontrollable external elements. Nevertheless, there is promise in adopting protected cultivation techniques to optimize crop yield and resilience. Controlled environment agriculture, referred to as protected cultivation (Jensen, 2002), offers a highly product and resource-conserving alternative. It also aids in safeguarding the environment by effectively managing water and land use.

Studies have highlighted the impact of high insect pest infestation on crop yields in open-field systems (Nguyen *et al.*, 2009). However, within protected cultivation environments like poly houses, there is potential to optimize climatic conditions, offering a sustainable approach for vegetable production even in adverse climates. Research, such as that by Korawan *et al*. (2013), demonstrates the thriving potential of vegetables in these controlled environments, exhibiting superior attributes such as optimal size, shape, color and consistently high-quality yields, even under challenging climatic conditions. Studies also indicate that broccoli yield significantly improves under naturally ventilated greenhouse conditions compared to open fields (Thakur *et al*., 2016). Microclimatic alterations within protected structures have been observed to influence crop water requirements and enhance crop quality compared to open-field cultivation (Sojitra *et al*., 2023; Santosh, 2021). Various research efforts have investigated factors affecting broccoli growth and yield in different conditions, including microclimatic parameters, covering materials, intercropping, irrigation levels (Díaz, 2009; Demir and Polat, 2011; Ayas *et al*., 2011; Yildirim and Durak, 2017; Hashem and Abd-Elrahman, 2016; Hussain *et al*., 2016; Chand *et al*., 2017).

This study aims to address this gap by examining irrigation regimes broccoli growth in a natural ventilated net-cum-polyhouse, especially pertinent in semi-arid regions with erratic rainfall like the Saurashtra region. The findings will contribute significantly to understanding optimal irrigation practices in broccoli cultivation under protected environments, offering valuable insights for farmers seeking to enhance produce yield in such challenging climatic conditions.

Materials and Methods

A field experiment was conducted within a natural ventilated net-cum-polyhouse at Junagadh Agricultural University, situated at the foothills of Girnar (21.52 °N latitude and 70.47 °E longitude, at an altitude of 107 m above mean sea level). The net-cum-polyhouse, measuring 12 m × 5 m in an east-west direction, was constructed with a ridge height of 5.30 m and an eave height of 4.0 m. To ensure adequate ventilation, 20% of the floor space area was kept open in the ridge vent space.

The structure was adapted using two types of covering materials: 200 µ UV-stabilized plastic and 50% white shade net. The top was covered with 200 µ UV-stabilized plastic, while the sides were covered with 50% white shade net. The study area experiences a typical subtropical, semi-arid climate, characterized by cold and dry winters, hot and dry summers, and warm, moderately humid conditions during the monsoon season. Over the last 35 years, the weekly daily maximum and minimum temperatures ranged from 29.5^{0}C to 39.4^{0}C and 10^{0}C to 26.7^{0}C, respectively, with relative humidity varying in between 51% to 81%. The annual mean rainfall and evaporation in the study area are recorded at 950 mm and 2482 mm, respectively.

The irrigation regimes were applied at the 0%, 80%, 60% and 40% of crop water requirement. Therefore, broccoli seedlings of the NS 50F1 hybrid (Namdhari Seeds) were grown in plug trays within the protected structure to ensure better germination (Sojitra *et al.*, 2022). A soilless media mix comprising a 2:1 ratio of cocopeat to vermicompost was prepared in grow bags measuring 20 cm × 20 cm × 25 cm (length, width and height). A drip irrigation system was installed, and the grow bags were arranged at a spacing of 0.30 m by 0.30 m. Healthy 45-day-old broccoli seedlings were transplanted in the second week of October for both years into the grow bags. The experiment was replicated four times, with six plants sown in each replication, following the large plot technique and analyzed using a simple completely randomized design.

Irrigation water requirements were scheduled using the FAO 56 method (Allen *et al*., 1988). Sensors for climatic parameters such as temperature, relative humidity, solar insolation and light intensity were integrated into a data logging system to record data. The recorded minimum and maximum temperatures, relative humidity, solar insolation data were used to calculate ET_0 following the FAO-56 method. Irrigation regimes (0%, 80%, 60% and 40% of ET_c) were applied throughout the broccoli crop season to assess their impact on broccoli cultivation in soilless media within the natural ventilated net-cum-polyhouse.

Fertigation, which forms the basis of soilless cultivation, necessitates proper macro and micro-nutrients at each stage of crop growth. Broccoli is moderately sensitive to salt tolerance and therefore, the EC was maintained below 2.5 ds/m and the pH ranged in between 5.5 to 6.5 as recommended by Trejo-Tellez and Gomez-Merino (2012). A recommended fertilizer dose of 150:60:60 N_2O, P_2O_5 and K_2O kg/ha was applied in 11 splits during different growth stages to reduce the EC of fertigation solution. Throughout the growth stages, 7%, 12% and 6% of the recommended fertilizer doses of NPK were applied in initial, mid, and end stages, respectively. Additionally, micronutrients like B, Mo, Mn, and Zn were applied at specific rates and stages of crop growth.

Various parameters, including stem diameter, plant height, number of leaves per plant, plant canopy, curd diameter, curd weight and overall yield, were analyzed to study the effect of different irrigation regimes on broccoli crop. In addition to yield and yield attributes, the Stewart model was utilized to establish relationships between yield and ET (Doorenbos and Kassam, 1979):

$$\left(1-\frac{Y_a}{Y_m}\right)=k_y\left(1-\frac{ET_a}{ET_m}\right) \quad (1)$$

Where,

Y_a = Actual yield (t/ha).

Y_m = Maximum yield (t/ha).

ET_a = Actual evapotranspiration (mm).

ET_m = Maximum evapotranspiration (mm).

k_y = response factor of broccoli to deficit irrigation.

The water use efficiency (WUE) was determined to evaluate the productivity of irrigation in the each treatment. WUE used to promote the efficient use of irrigation water at the crop production level. WUE was calculated as the ratio of yield (YLD) to ET_a, given as:

$$WUE\left(\frac{kg}{m^3}\right)=\frac{YLD}{ET_a} \quad (2)$$

Results and Discussion

Irrigation Water Requirement

Initially, irrigation water was applied at a rate of 5 mm before sowing to aid in root settlement. The average water requirement over the two-year period was found to be 140 mm, 113 mm, 86 mm, and 59 mm for irrigation regimes set at 0%, 80%, 60% and 20%, respectively, within the natural ventilated net-cum-polyhouse. This observation could be attributed to the relatively shorter crop growth period, reduced solar insolation, and higher relative humidity levels observed within the structure. Additionally, the wind velocity within the structure remained notably low due to its complete enclosure, contributing further to the reduced irrigation water requirement.

Crop on Yield and Yield attribute

The effect of irrigation regimes on yield and yield attributes were found significant except No. of leaves per plant for broccoli cultivation natural ventilated net-cum-poly house as shown in Table 1. The stem diameter (58.50 mm), plant height (36.57 cm), plant canopy (0.43 m^2), curd diameter (16.22 cm), curd weight (405.13 g) and yield (41.71 t/ha) were observed higher at 0% irrigation regimes. However it was found at par with 80% irrigation regime.

Yield Response to Deficit irrigation

The Crop yield response factor (k_y) showcases a linear correlation between the reduction in relative water consumption and the subsequent decrease in relative yield as depicted in Table 2 and Fig.1. It elucidates how yield responds concerning the reduction in water usage per unit. This factor explains the proportional decline in yield due to a decrease in water consumption per unit (Stewart

Table 1 : Influence of Irrigation regimes on broccoli crop under Natural Ventilated net-cum-poly house.

Treatment	Stem diameter, mm	Plant height, cm	No of leaves per plant	Plant canopy, m^2	Curd diameter, cm	Curd weight, g	Yield, t/ha
T_1	58.50	36.57	15.72	0.43	16.22	405.13	41.71
T_2	55.31	35.38	15.25	0.38	14.71	369.94	39.69
T_3	51.29	33.58	15.32	0.34	12.58	294.49	27.12
T_4	43.92	31.82	15.00	0.32	11.96	227.55	16.01
S.Em.±	1.71	1.05	0.41	0.02	0.60	12.34	1.14
C.D. at 5%	5.12	3.16	NS	0.05	1.80	36.99	3.41
CV%	8.01	7.52	6.61	11.65	10.63	9.32	8.95

Table 2: Relationship between Relative yield to relative water use, yield response and Water Use Efficiency (WUE).

Irrigation regimes	Y_a	ET_a	$\frac{ET_a}{ET_m}$	$\frac{Y_a}{Y_m}$	$1-\left(\frac{ET_a}{ET_m}\right)$	$1-\left(\frac{Y_a}{Y_m}\right)$	K_y	WUE (kg/m^3)
0%	41.7	140	1.00	1.00	0.00	0.00	0.00	29.80
20%	39.7	113	0.81	0.95	0.19	0.05	0.25	35.17
40%	27.1	86	0.61	0.65	0.39	0.35	0.91	31.52
60%	16.0	59	0.42	0.38	0.58	0.62	1.07	27.08

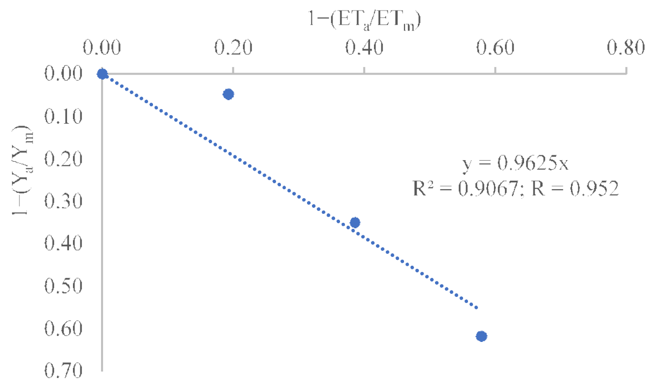

Fig. 1 : Relationship between relative yields to relative crop evapotranspiration for broccoli under natural ventilated net-cum poly house.

et al., 1975; Doorenbos and Kassam, 1979). The seasonal yield response factor was calculated as 0.9625 for the various irrigation treatments, as illustrated in Fig. 1. The values of k_y demonstrated an increase with higher water deficits. The Water Use Efficiency (WUE) values also decreased as the irrigation water amount decreased. The most significant WUE was reaching as 35.17 kg/m^3 was obtained from the 20% irrigation regime followed closely by the 40% irrigation regime. However, although WUE was higher in the 40% irrigation regime, the yield was not significant notable.

The current findings are in line with prior studies conducted by Ayas *et al.* (2011) in unheated greenhouse conditions regarding broccoli cultivation. Moreover, Yildirim and Durak (2017) highlighted that optimal broccoli yield and quality were attained under full irrigation. They suggested that amidst water scarcity, maintaining an economically viable yield and quality is achievable by conserving 30% of water. Notably, significant yield reduction occurred beyond 30% irrigation stress, consistent with the outcomes observed in this study. Ayas *et al.* (2011) identified that irrigating at 0.75 times the evaporation rate of Class A Pan significantly enhanced water use efficiency, recommending this approach for water-scarce environments in unheated greenhouse conditions for broccoli cultivation. Similarly, Hussain *et al.* (2016) proposed an optimal irrigation schedule, suggesting that irrigating broccoli at field capacity every 10 days rather than a 5 day interval maximizes gross returns. Chand *et al.* (2017) demonstrated that applying an irrigation regime of 80% led to significant improvements in various growths and yield attributes findings that correspond with the results obtained in the present study.

Conclusion

The impact of irrigation regimes significantly influenced on various crop parameters including curd weight and yield. The highest curd weight and yield was found significantly higher at full irrigation. However, yield and yield attribute parameter were found at par with 80% of irrigation water requirement. Water Use Efficiency (WUE) was also found highest at irrigation regime of 80% followed by irrigation regimes 60% and full irrigation. However, irrigation regimes beyond 80% significantly reduced the yield. This suggests that irrigation regimes of 80% found to be beneficial for broccoli cultivation in water-scarce conditions under natural ventilated net-cum-polyhouse.

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