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Enhancing Capsicum Cultivation under Polyhouse, Shadenet House and Open Field Conditions with Drip Fertigation

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Abstract: Capsicum cultivation is a highly challenging task in open field conditions because of the extreme climatic conditions and poor input delivery system. Hence, the protected cultivation of capsicum is catching up. The present study evaluates the comparative performance of polyhouse, shadenet house and open field conditions on the biometric, yield, fruit quality and economics of capsicum using drip and fertigation system. The study also determines the optimum dose of irrigation water and fertilizer application using drip irrigation methods under different protected cultivation structures. The study was conducted at Precision Farming Development Centre, IIT Kharagpur, for two consecutive years during 2022 and 2023. The irrigation water requirement of capsicum under polyhouse, shadenet house and open field conditions was estimated using FAO-56 Penman Monteith approach. When compared to open field cultivation, drip irrigated capsicum requires approximately 35.2% less water under polyhouse conditions and 25.5% less under shade net houses. The study also found that biometric parameters, yield and quality of capsicum are superior under polyhouse in comparison to the capsicum grown under shadenet and in open field conditions. Polyhouse treatments, particularly 100% RDF with 80% WR, demonstrated superior biometric parameters, quality metrics, and water productivity compared to other treatments. Capsicum grown under shadenet house conditions with 120% RDF with 80% WR also showed enhanced yield and quality over open field conditions. Economic analysis revealed that polyhouse cultivation, despite higher initial costs, yielded the highest net profit and benefit-cost ratio, followed by shadenet house and open field conditions. These findings underscore the importance of controlled environments in improving capsicum production and economic returns, highlighting the potential of polyhouses and shadenet houses in optimizing crop performance and resource use efficiency.

Introduction

Shrinkage of land, degradation of natural resources, and urbanization created havoc issues in agriculture for fulfilling the demands of a growing population in the context of climate change (Das et al., 2021; Hossain et al., 2021; Sairam et al., 2023; Santosh et al., 2024a). To overcome problems, several improved packages of practices for crop production and input optimization have become essential (Midya et al., 2021; Maitra et al., 2023a; Mukesh et al., 2024; Ray et al., 2024). Further, urbanization led to a diversity in human food habits, which directed progressive farmers to grow various crops with superb quality produce (Maitra et al. 2024a). In this way, protected cultivation has appeared as a highly productive farming technology that conserves resources and ensures quality output under controlled environmental conditions (Maitra et al., 2023b). The protected cultivation technology eases a hassle-free environment that facilitates farmers to grow various crops, targeting market needs (Maitra et al., 2024a).

Capsicum (*Capsicum annuum* L.) is a commercial vegetable crop famous for its nutritional values, having

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high levels of vitamins A and C, capsaicin and antioxidants. The significant market demand for capsicum has been increased in recent years because of its numerous culinary uses and health advantages. However, growing capsicum has several difficulties, especially when enhancing quality and production through environmental condition optimization. Inferior production results are frequently the result of traditional open-field cultivation's vulnerability to climatic fluctuations, pest and disease pressures, and unbalanced water and fertilizer availability (Maitra et al., 2024b).

Technological developments in protected cultivation, such as shadenet houses and polyhouses, present possible answers to these problems. Enclosed structures with translucent or semi-transparent coverings, known as polyhouses, offer a regulated environment that can improve crop performance and lessen the negative impacts of external climate changes. Compared to polyhouses, shadenet houses offer less control, but they still give substantial protection against pests and excessive sun radiation, improving crop conditions. (Yang et al., 2022).

Drip irrigation and fertigation systems further enhance the efficient management of water and nutrients in these controlled environments. Water is delivered to the root zone directly via drip irrigation, which minimizes water waste and encourages healthy plant growth (Santosh and Tiwari, 2017). For high-value vegetable crops like capsicum, fertigation, which adds fertilizers through the irrigation system, ensures accurate nutrient delivery as per crop needs (Santosh et al., 2023). Fertigation increases nutrient use efficiency by 30-40%, prevents soil degradation, reduces the cost of fertilizer application, minimizes groundwater pollution, and prevents losses through runoff and leaching (Santosh et al., 2024b). The yield, quality, and efficiency of resource utilization can all be significantly increased by combining these cutting-edge input delivery approaches.

The present research aims to study the effect of polyhouse, shadenet house and open field cultivation on the biometric parameters, yield, quality and economic viability of capsicum using drip and fertigation systems. Through an organized study of these diverse growing environments, the research aims to offer knowledge about the best practices for maximizing capsicum yield under varied agroclimatic circumstances.

Material and Methods

The research was conducted at experimental farm of Precision Farming Development Centre, Agricultural and Food Engineering Department, IIT Kharagpur, India. The farm is situated at latitude of 22^{0}20’ N latitude and 87^{0}20’ E longitudes, with mean sea level of 48 m. The research location belongs to the sub-humid region receiving rainfall of around 1500 mm. Prevailing temperature ranges between 9^{0}C and 26^{0}C during winter and 27.2^{0}C and 42^{0}C during summer months. The relative humidity of the location is ranging between 70% and 99% for maximum and 22% to 70% for minimum recording.

The research was conducted in two different types of protected cultivation structures which includes polyhouse and shadenet house. Both structures have the width of 8 m and the length of 12.5 m and height of structures are 4 m. The microclimatic data such as temperature, relative humidity, sunshine radiation and wind velocity were collected using standard instruments such as maximum – minimum thermometer, wet bulb and dry bulb thermometer, lux meter and anemometer respectively. The climatic data for open field conditions were also recorded during the research. The daily irrigation water requirement of the capsicum was estimated using with the following relationship

$$WR = ET_0 \times Kc \times Wp \times A$$

Where,

WR = Crop water requirement (L d^{-1})

ET_0 = Reference evapotranspiration (mm d^{-1})

Kc = Crop coefficient (Table 1 lists typical values for Kc ini, Kc mid, and Kc end for various winter vegetable crops)

Wp = Wetting fraction (taken as 1 for close growing crops)

A = Plant area, m^2 (i.e. spacing between rows, m x spacing between plants, m)

The daily meteorological data recorded inside polyhouse, shadenet house and in open field conditionsfor the two consecutive years 2022-2023 were used to estimate reference evapotranspiration (ET_0).The modified Penman-Monteith method as mentioned by Allen et al. (1998) was used to compute reference evapotranspiration (ET_0). This study estimated the water requirement of capsicum under polyhouse and shadenet house and in open field conditions. The Randomized block design (RBD) with thirteen treatments and three replications was used to set up the experiment. The seedlings of capsicum transplanted on a raised bed with varying treatments. Below are the specifics of the treatments that were applied in Experiment.

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T_1 : 120 % RDF with 100% WR in polyhouse	T_8 : 120 % RDF with 80% WR in shade net house
T_2 : 120 % RDF with 80% WR in polyhouse	T_9 : 100 % RDF with 100% WR in shade net house
T_3 : 100 % RDF with 100% WR in polyhouse	T_{10} : 100 % RDF with 80% WR in shade net house
T_4 : 100 % RDF with 80% WR in polyhouse	T_{11} : 80 % RDF with 100% WR in shade net house
T_5 : 80 % RDF with 100% WR in polyhouse	T_{12} : 80 % RDF with 80% WR in shade net house
T_6 : 80 % RDF with 80% WR in polyhouse	T_{13} : 100 % RDF with 100% WR in open field (Control)
T_7 : 120 % RDF with 100% WR in shade net house	

The recommended dose of fertilizer 250:150:150 kg/ha N:P_2O_5:K_2O was considered for *California wonder* variety of capsicum growth utilizing fertigation method. A drip system is used to apply the appropriate dosage of fertilizers, which are properly dissolved and applied weekly once. A sub surface drip irrigation system was designed and installed on an area of 100 m^2. The drip system consisted of the following components: Strainer filter, 62 mm diameter main pipe line (5 m long Poly Vinyl Chloride (PVC) buried at depth of 0.5 m below ground level), 16 mm LLDPE lateral line 12 m long and a inline drippers of 4 Lh^{-1} discharge per 4 plants. Capsicum was planted on raised bed. The standard horticultural management practices, such as weed control, protection against pests, etc. were carried out throughout the experiment. Plant growth parameters measurements were included seasonal increase in plant height, primary branches, the number of green leaves, number of flowers, number of fruits and yield was recorded. Statistical analysis was performed using SPSS software package to test the significance of different treatments individually as well as in combinations experimental ANOVA was performed statistical analysis of data. In order to the compare the results between the treatment means and variance were tested at 5% significance level.

Results and Discussion

The presence of polyethylene cover or shadenet causes changes in the climatic conditions inside polyhouse and shadenet house in comparison to those open field conditions. Radiation and air velocity are reduced, temperature and water vapour pressure of the air increases. Each of these changes has its own impact on the growth, production and quality of the capsicum crop inside the polyhouse and shadenet house.

Daily variations of maximum and minimum temperature in poly house, shadenet house and for open field condition were recorded from November to February for consecutive two years (2021-2023). Temperature of poly house showed that the use of polyethylene exerted an influence on temperature. Interception of air within the structure increases the daily maximum and minimum temperature compare to outside environment. The values of maximum and minimum temperature recorded in shadenet house were less in comparison to temperature recorded inside the polyhouse and greater in comparison to the open field environment.

Weekly average of daily maximal and minimal ambient temperatures during the winter season (November to February) in poly house, shadenet house and in open condition are shown in the Figure 1. Polyhouse recorded the highest values for maximum or minimal ambient temperatures in comparison to both shadenet and open field conditions for throughout crop period. Shadenet house recorded higher temperature compare to the open condition for whole crop period but lesser than the temperature recorded in Polyhouse. Weekly average of daily maximum temperature for the crop season shows that the highest value of maximal temperature (42^0C) recorded in polyhouse for the second week after transplantation. In the month of January (8 weeks after transplantation), playhouse recorded almost the same value of minimal and maximal temperature as in open conditions. Poly film increases the temperature due to conversion of solar radiation to long wave radiation inside structures. Similar trend was observed in many studies for maximum and minimum temperature inside polyhouse and shadenet house (Thakur and Sharma, 2005; Kumar et al., 2014; Tezcan et al., 2023).

Figure 2 shows that the values of daily mean relative humidity are greater in poly house and shadenet house by 2–20% and 3-16%, respectively in comparison with the open field conditions. During extreme winter of December and January (6-12 weeks after transplantation) more humidity observed in polyhouse compares to open field conditions. The reason for the greater humidity inside the polyhouse and shadenet house may be the indication of decreased evaporation which was associated with the use of cladding materials and a significant reduction in wind speed (Reddy et al., 2021). The same trend of relative humidity was found in some other studies (Mahmood et al., 2018; Gruda et al., 2019; Sharma et al., 2024).

Figure 3 shows that poly film transmits solar radiation about 60 to 80%, and shade net transmits solar radiation about 70 to 94% depending upon the sunshine hours. During the winter of December and January (8-12 weeks after transplantation) small difference (20%) in receiving

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net radiations by the plant was observed between playhouse and open conditions. As the temperature increases during February month (14-18 weeks after transplantation), this difference in receiving solar radiation is also increased by up to 40%. The cladding materials covering on playhouse, significantly change the radiation balance relatively to the external environment, because of the attenuation (absorption and reflexion) of the incident solar radiation, resulting in a reduction of the internal radiation balance and, consequently, affecting evapotranspiration (Nikolaou et al., 2021; Kittas et al, 2022; Kumar et al., 2022).

Application of FAO-56 Modified Penman-Monteith (PM) equation was used for estimating capsicum crop water requirement; the microclimate data plays an important role in irrigation planning. Weekly average of daily reference evapotranspiration under polyhouse, shadenet house and open condition is shown in Figure 4. Seasonal ET_0 of playhouse and shade net houses are quite low when compared with that of irrigated crops outdoors during winter. The values of ET_0 range from 1.6 to 2.5 mm day^{-1} and 1.9 to 3.1 mm day^{-1} for playhouse and shade net house, respectively, which is much lower compared to open condition.

The crop evapotranspiration was estimated by multiplying reference evapotranspiration with crop coefficient based on crop growth stage. In present study the value for crop coefficient (Kc) was taken from FAO-

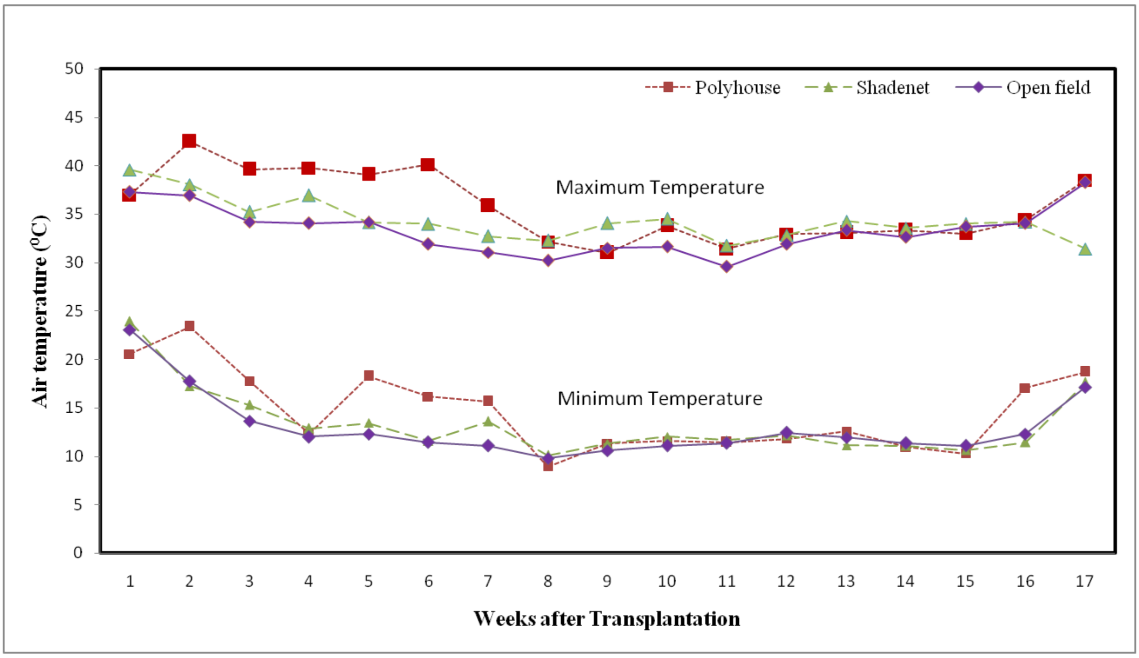

Figure 1. Weekly average of daily maximum and minimum temperature recorded during the period of experimentation in polyhouse, shadenet house and open condition.

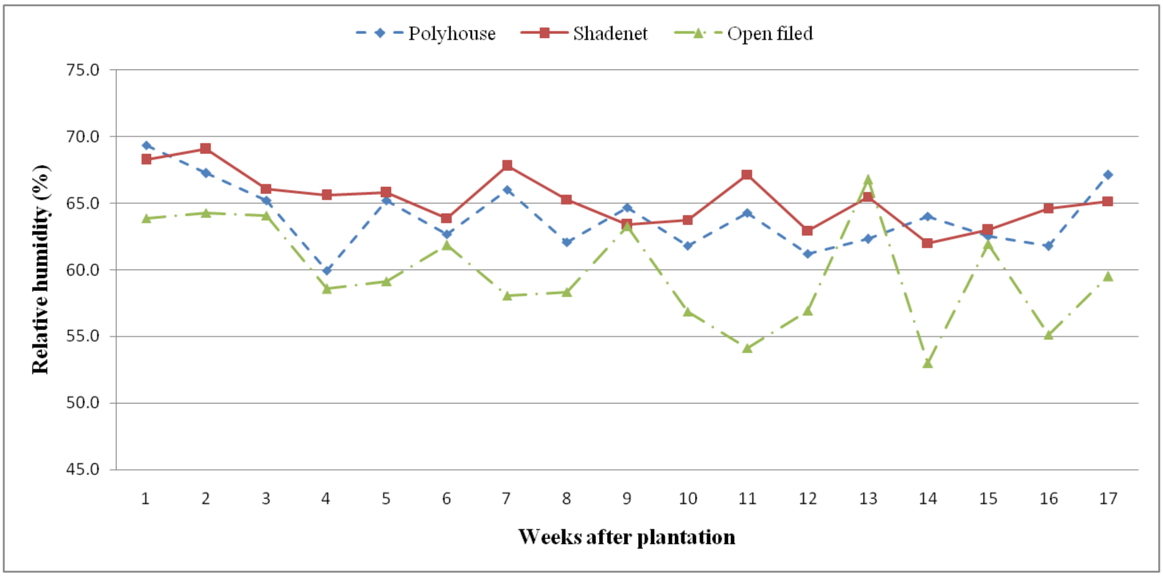

Figure 2. Weekly average of daily mean relative humidity recorded during the period of experimentation in polyhouse, shadenet house and open condition.

50 (Allen et al., 1998). The irrigation water requirement of capsicum using drip irrigation was estimated for polyhouse, shadenet house and for open condition which is presented in Table 1.

environment for enhancing the crop performance. This greater biometric performance of crop found in polyhouse indicated the positive response of controlled microclimatic conditions with regulated temperature,

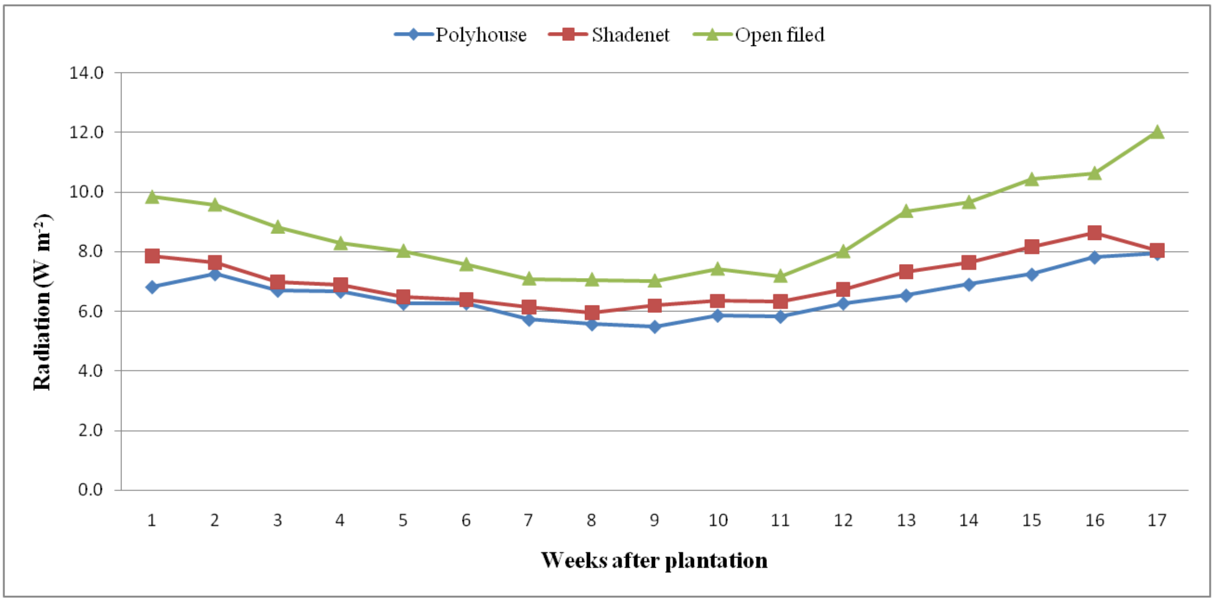

Figure 3. Weekly average of daily radiation (W m^{-2}) recorded during the period of experimentation in polyhouse, shadenet house and open condition.

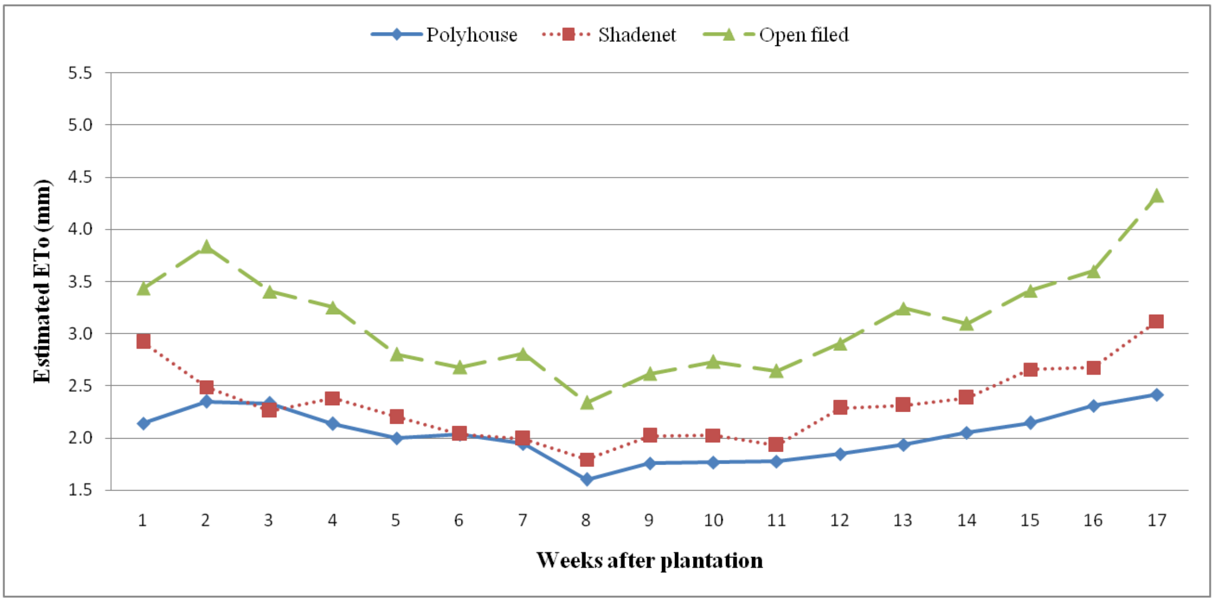

Figure 4. Weekly average of daily reference evapotranspiration ET_0 (mm) estimated for the period of experimentation in polyhouse and open condition.

Two years of pooled data of biometric attributes like plant height, number of leaves per plant, number of flowers per plant, number of fruits per plant, fruit weight and yield of capsicum crop are presented in the Table 2. The results from Table 2 revealed that all biometric parameters of crop (Height, number of branches, number of leaves per plant, number of flowers/ plants, leaf area index and days requires to harvest) are significantly superior in the polyhouse treatments in comparison to shadenet house treatments and open field conditions. The above findings highlight the importance of controlled humidity and light radiation favorable to robust vegetative growth (Kumar et al., 2022). The greater number of leaves and flowers may be the result of increased photosynthetic performance under controlled environments (Yadav et al., 2024). Study showed that influence of controlled climate control in polyhouse and partial microclimate control in shadenet house improve the biometric characteristics of capsicum in comparison with the open field cultivation (Pramanik et al., 2020).

Biometric parameters of treatment T_4 (100 % RDF with 80% WR in polyhouse) were found to be superior in

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Table 1. Estimated water requirement of capsicum under poly house, shadenet house and for open field condition.

Weeks after plantation	Crop water requirement, L plant^{-1} day^{-1}		
	Poly house	Shadenet house	Open field
1	0.32	0.44	0.52
2	0.39	0.41	0.63
3	0.42	0.40	0.61
4	0.41	0.46	0.62
5	0.41	0.45	0.58
6	0.45	0.45	0.59
7	0.46	0.47	0.66
8	0.40	0.45	0.58
9	0.46	0.53	0.69
10	0.46	0.52	0.70
11	0.45	0.49	0.67
12	0.46	0.57	0.72
13	0.47	0.56	0.79
14	0.49	0.57	0.74
15	0.50	0.62	0.80
16	0.53	0.61	0.83

Table 2. Plant growth characteristics of capsicum under different climatic conditions (Pooled data of two crop season 2022-23 and 2023-24).

Treatment	Height (cm)	Number of Branches	Number of leaves/plant	Number of flowers/plant (No.)	Leaf area index	Days from ripe to harvest
T_1	52.5	5.95	126.7	54.0	15.7	110.1
T_2	45.1	6.01	127.0	55.3	16.7	109.0
T_3	53.7	6.09	132.3	58.3	18.0	107.6
T_4	61.3	6.13	137.7	60.3	18.7	106.9
T_5	47.3	6.01	111.0	57.7	16.7	109.0
T_6	42.7	6.01	105.3	58.3	16.7	109.0
T_7	46.3	5.66	119.3	39.0	11.0	115.1
T_8	49.0	5.82	129.3	48.3	13.7	128.6
T_9	44.0	5.78	121.7	44.0	13.0	113.0
T_{10}	45.0	5.68	125.0	42.0	11.3	124.6
T_{11}	42.3	5.60	123.3	42.0	10.0	133.7
T_{12}	41.0	5.62	110.3	38.0	10.3	138.0
T_{13}	47.7	5.68	108.3	35.7	11.3	114.8
CD (0.05)	**4.74**	**0.92**	**16.8**	**14.0**	**5.4**	**4.23**

comparison to all other combinations of water and fertilizer dose treatments in polyhouse cultivation. The treatment T_4 may be receiving the optimum amount of water and nutrients, which leads to enhanced growth parameters (Soussi et al., 2022). Similarly, the biometric parameters and yield of capsicum crop under shadenet house were found to be superior with treatment T_8 (120 % RDF with 80% WR in shadenet house) as compared to the rest of the treatments inside shadenet house and for open condition treatment. Study conducted by Singh et al., (2020) shows that the different irrigation and fertigation level may influence the biometric characteristics of capsicum under protected cultivation. This indicates that the combination of greater amount of fertilizer and optimum amount water in semi-controlled environment likely to increase the crop performance (Patil et al., 2020).

The yield and yield attributes of capsicum under treatments were presented in the table 3. Yield of different treatments shows statistically significant difference between treatments. Greater yield and yield attributes were recorded under treatment T_4, which is followed by the treatment T_3 (100 % RDF with 100% WR in polyhouse) and is statistically at par with highest yield of the treatment T_4. Yield of treatment T_9 (100 % RDF with 100% WR in shadenet house) recorded statistically at par yield with the treatment T_8. Least yield was found for treatment T_{13} (100 % RDF with 100% WR

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in open field condition, control). This result highlights the importance of controlled environment to get greater yield (Shukla et al., 2019). Based on the analysis of data, it shows that all treatments under polyhouse recorded highest yield in comparison to shadenet house treatments and open field conditions. Within the polyhouse application of 100% recommended dose of fertilizer through drip fertigation and 80% of crop water requirement resulted in higher yield. In the shadenet house, application of 100% recommended dose of fertilizer and 100% required water requirement met through drip system can be recommended to achieve higher yield. Study conducted by Kumari et al. (2021) showed that yield of capsicum would be positively influenced by optimum irrigation and fertigation level under protected cultivation structures.

Quality characteristics and water productivity of capsicum for different treatments were presented in the Table 4. From Table 4, it is evident that dry matter content ranges between 5.2% and 5.6%, with no significant difference between the treatments. There was a significant difference among the treatments for C content. The highest C content was found in treatment T_4 (179.4 mg/100g) under polyhouse and lowest C content recorded in treatment T_{10} (166.2 mg/100g) under open field conditions. This result highlights the importance of controlled environment for enhancing the fruit quality parameter. Water productivity was found to be highest for treatment T4 (11.47 t/ha/mm) under polyhouse, and the lowest was found with Treatment T_{13} (1.97 t/ha/mm) for open field conditions. This huge gap in water productivity highlights the benefits of a controlled envir-

Table 3. Yield attributes and fruit yield of capsicum under different climatic conditions (Pooled data of two crop seasons 2022-23 and 2023-24).

Treatment	Number of fruits/plant (No.)	Fruit length (cm)	Fruit width (cm)	Fruit girth (cm)	Fruit weight (g)	Yield (t/ha)
T_1	15.7	8.22	7.37	19.49	172.7	85.1
T_2	16.7	8.33	7.48	19.76	172.3	96.6
T_3	18.0	8.59	7.71	20.38	186.0	108.7
T_4	18.7	8.77	7.87	20.80	194.0	113.7
T_5	16.7	8.54	7.67	20.26	163.7	86.5
T_6	16.7	8.59	7.71	20.38	158.3	83.5
T_7	11.0	6.90	6.19	16.37	168.7	57.5
T_8	13.7	7.72	6.93	18.30	172.7	73.8
T_9	13.0	7.34	6.59	17.41	158.0	62.8
T_{10}	11.3	7.17	6.43	16.99	157.3	52.9
T_{11}	10.0	7.17	6.43	16.99	143.7	43.4
T_{12}	10.3	6.81	6.11	16.16	143.0	42.7
T_{13}	11.3	6.61	5.93	15.68	140.0	37.0
CD (0.05)	**14.0**	**1.26**	**1.08**	**1.32**	**14.2**	**12.6**

Table 4. Quality and water productivity of capsicum under polyhouse, shadenet and open field conditions (Pooled data of two crop season 2022-23 and 2023-24).

Treatment	Dry matter (%)	Vit C (mg/100g)	Capsaicin Content (%)	Water productivity (t/ha/mm)
T_1	5.3	177.7	0.35	6.87
T_2	5.3	173.3	0.35	9.75
T_3	5.2	174.4	0.37	8.77
T_4	5.2	179.4	0.37	11.47
T_5	5.3	177.2	0.36	6.98
T_6	5.3	178.9	0.36	8.42
T_7	5.6	177.2	0.35	4.11
T_8	5.4	170.0	0.36	6.59
T_9	5.5	168.3	0.36	4.49
T_{10}	5.6	166.2	0.34	4.72
T_{11}	5.6	165.0	0.34	3.10
T_{12}	5.6	168.3	0.34	3.81
T_{13}	5.6	168.3	0.31	1.97
CD (0.05)	NS	5.3	NS	3.46

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Table 5. Cost economic of Capsicum under polyhouse, shadenet and in open field condition.

Sl. No.	Cost of economics per hectare of land	Polyhouse	Shadenet house	Open field conditions
1	Fixed costs of structures, Rs/ Season/ 100 m^2	11111.00	6111.00	1111.00
2	Variable cost, Rs/ Season/ 100 m^2	6630.00	7380.00	8380.00
3	Gross cost of Production (Variable + Fixed), Rs / Season/ 100 m^2	17741.00	13491.00	9491.00
4	Yield of produce (t/ha)	113.7	73.8	37
5	Yield of produce (kg/ 100m^2)	1137	738	370
6	Income from produce @ 30 Rs./kg (Rs.)	34110.00	22140.00	11100.00
7	Net profit (Rs/ha)	16369.00	8649.00	1609.00
8	Gross benefit cost (B-C)	1.92	1.64	1.17

Figure 5. Capsicum cultivation under polyhouse, shadenet house and in open field cultivation.

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onment (polyhouse) and a semi-controlled environment (shadenet house) over open field cultivations (Yang et al., 2022; Kittas et al., 2022).

The economic analysis for capsicum crop cultivation under polyhouse, shadenet house and open field conditions were presented (Table 5) and shows significant variations in cost and income. The fixed cost of structures and irrigation systems for a season per 100 m^2 were highest for polyhouse (Rs. 11,111) followed by shadenet house (Rs. 6,111) and lowest for open field conditions (Rs. 1,111). After adding the variable costs, highest gross cost of cultivation per season per 100 m^2 found for polyhouse (Rs. 13,491) followed by shadenet house (13,491) and lowest for open field conditions (Rs. 9,491). After the calculations of gross profit and net profit, highest gross benefit cost (BC) ratio was found with polyhouse cultivation (1.92), followed by shadenethouse (1.64) and lowest for open field conditions (1.17).

The results suggest that regardless of the higher initial investment, cultivation under polyhouse exhibits a more profitable return on investment due to better control over environmental factors, which enhances yield and quality of produce (Kumar et al., 2020). In contrast, open field conditions, with the lowest costs, also result in the lowest yield and profit, indicating the limitations of non-controlled environments in maximizing capsicum production. The intermediate performance of shadenet house conditions suggests a balance between cost and yield, making it a viable option for growers seeking moderate investment with reasonable returns. These findings highlight the importance of adopting advanced cultivation technologies like polyhouses to improve economic outcomes in capsicum production (Pramanik et al., 2020; Rani et al., 2024).

Conclusion

The study conducted on capsicum cultivation under polyhouse, shadenet house and open field conditions highlighted the importance of controlled environments for enhanced yield. The biometric parameters, yield attributes, yield, fruit quality parameters and economics returns of capsicum significantly greater in polyhouse conditions. Treatments under polyhouse, particularly with optimal water and nutrient supply (T_4), recorded the greater quality metrics, yield, and water productivity, thereby demonstrating the efficacy of controlled environments in enhancing crop performance and resource use efficiency. Capsicum cultivation under shadenet conditions provided moderate benefits with maintaining the balance between investment and profit with highlighting the limitations of cultivation under less controlled environments. Moreover, the economic analysis supported the greater profitability even with greater investment for polyhouse cultivation, due to much higher yield and income. These results accentuate the benefits of adopting protected cultivation technologies especially polyhouse to enhance the economic benefits ensure sustainable agricultural practices. Overall, the controlled environment provided by polyhouses enables better management of microclimate, leading to enhanced crop quality, yield, and economic returns, making it a viable option for growers seeking to optimize their production systems. Further research is need for optimizing the water and fertilizer application for capsicum under polyhouse and shadenet house of different climatic and different soil conditions. Sustainable and organic nutrient solutions may also future research for growing capsicum under protected cultivation.

References

Allen, R.G., Pereira, L.S., Raes, D., & Smith, M. (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *FAO, Rome*, *300*(9), D05109.

Das, P., Pramanick, B., Goswami, S.B., Maitra, S., Ibrahim, S. M., Laing, A.M., & Hossain, A. (2021). Innovative land arrangement in combination with irrigation methods improves the crop and water productivity of rice (*Oryza sativa* L.) grown with okra (*Abelmoschus esculentus* L.) under raised and sunken bed systems. *Agronomy*, *11*, doi:10.3390/ agronomy11102087.

Gruda, N., Bisbis, M., & Tanny, J. (2019). Influence of climate change on protected cultivation: Impacts and sustainable adaptation strategies-A review. *Journal of Cleaner Production*, *225*, 481-495, https://doi.org/10.1016/j.jclepro.2019.03.210

Hossain, A., Pramanick, B., Bhutia, K.L., Ahmad, Z., Moulick, D., Maitra, S., Ahmad, A., & Aftab, T. (2021) Emerging roles of osmoprotectant glycine betaine against salt-induced oxidative stress in plants: A major outlook of maize (*Zea mays* L.). In: *Frontiers in Plant-Soil Interaction: Molecular Insights into Plant Adaptation* (Eds. Aftab, T., Hakeem, K. R.), Academic Press, pp. 567–587.

Kittas, C., Baudoin, W., Kitta, E., &Katsoulas, N. (2022). Shertered horticulture adapted to different climate zones in Radhort Countries. *Italian Journal of Agrometeorology*, *2*, 3-16. https://doi.org/10.36253/ijam-1655

Kumar, S., Bairwa, D.S., Kumar, K., Yadav, R.K., & Yadav, L.P. (2022). Climate regulation in protected structures: A review. *Journal of Agriculture and Ecology*, *13*, 20-34. https://doi.org/10.53911/JAE.2022.13102

Kumar, S., Patel, N. B., &Saravaiya, S. N. (2014). Response of parthenocarpic cucumber to fertilizers and training systems under NVPH in subtropical conditions. *International Journal of Current Research*, *6*(8), 8051-8057.

Kumari, L., Hasan, M., Randhe, R. D., Singh, D. K., Singh, A. K., & Alam, W. (2021). Effects of mulching and irrigation levels on greenhouse capsicum (*Capsicum annuum*). *Indian Journal of Agricultural Sciences*, *91*(6), 833-6.

Mahmood, A., Hu, Y., Tanny, J., & Asante, E.A. (2018). Effects of shading and insect-proof screens on crop microclimate and production: A review of recent advances. *Scientia Horticulturae*, *241*, 241-251. https://doi.org/10.1016/j.scienta.2018.06.078

Maitra, S., Patro, T.S.S.K., Reddy, A., Hossain, A., Pramanick, B., Brahmachari, K., Krishna Prasad, K., Santosh, D.T., Mandal, M., Shankar, T., Sagar, L., Banerjee, M., Palai, J.B., Praharaj, S., & Sairam, M. (2023a). Brown top millet (*Brachiariaramosa* L. Stapf; *Panicum ramosum* L.) – The neglected and smart crop in fighting against hunger and malnutrition. In: *Neglected and Underutilized Crops*, Farooq, M. and Siddique, K.H.M., pp. 221–245. https://doi.org/10.1016/B978-0-323-90537-4.00012-0.

Maitra, S., Sahoo, U., Sairam, M., Gitari, H. I., Rezaei-Chiyaneh, E., Battaglia, M. L., & Hossain, A. (2023b). Cultivating sustainability: A comprehensive review on intercropping in a changing climate. *Research on Crops*, *24*, 702-15. https://doi.org/10.31830/2348-7542.2023.roc-1020.

Maitra, S., Sairam, M., & Santosh, D. (2024a). Evaluation of the growth, flower quality, yield and vase life of gerbera (*Gerbera jamesonii* L.) cultivars under open ventilated saw-tooth type polyhouse. *Research on Crops*, *25*, 104-09. https://doi.org/10.31830/2348-7542.2024.ROC-1055.

Maitra, S., Sairam, M., Santosh, D., Gaikwad, D.J., & Sahoo, U. (2024b). Growth, productivity and quality of colored capsicum (*Capsicum annuum* L.) as influenced by hybrids and plant growth regulators under controlled environment conditions. *Research on Crops*, *25*(2), 328-335. https://doi.org/10.31830/2348-7542.2024.ROC-1079

Midya, A., Saren, B.K., Dey, J.K., Maitra, S., Praharaj, S., Gaikwad, D.J., Gaber, A., Alhomrani, M., & Hossain, A. (2021). Crop establishment methods and integrated nutrient management improve: Part II. nutrient uptake and use efficiency and soil health in rice (*Oryza sativa* L.) field in the lower Indo-Gangetic plain, India. *Agronomy*, *11*(9), 1894. https://doi.org/10.3390/agronomy11091894

Mukesh, G., Sairam, M., Maitra, S., Gaikwad, D. J., Anuradha, N., Sahoo, U., & Pal, S. (2024). Performance Evaluation of Different Finger Millet (*Eleusine coracana* L. Gaertn.) Cultivars for Growth, Productivity and Nutrient Quality of Grains Under Hot and Subhumid Region of Odisha. *International Journal Experimental Research and Review, 39,* 01-14. https://doi.org/10.52756/ijerr.2024.v39spl.001

Nikolaou, G., Neocleous, D., Christou, A., Polycarpou, P., Kitta, E., &Katsoulas, N. (2021). Energy and water related parameters in tomato and cucumber greenhouse crops in semiarid mediterranean regions. A review, part I: Increasing energy efficiency. *Horticulturae*, *7*(12), 521. https://doi.org/10.3390/horticulturae7120521

Patil, R.T., Patil, B.C., Seetharamu, G.K., Mukund Shiragur, S.N., Ramanagoda, S.H., & Mahantesha, N.B.N. (2020). Effect of different photo-selective shade nets on growth and yield of fern. *International Journal of Ecology and Environmental Sciences*, *2*, 784-787.

Pramanik, K., Mohapatra, P.P., Pradhan, J., Acharya, L.K., & Jena, C. (2020). Factors influencing performance of capsicum under protected cultivation: A review. *International Journal of Environment and Climate Change*, *10*(12), 572-588. https://doi.org/10.9734/IJECC/2020/v10i1230339

Rani, N., Tiwari, D., Kaur, G., & Sharma, D. (2024). Enhancing agricultural productivity: A Comparative study of vegetable cultivation under polyhouse and open field conditions in Punjab, India. *Journal of Scientific Research and Reports*, *30*(7), 166-174. https://doi.org/10.9734/jsrr/2024/v30i72133

Ray, S., Maitra, S., Sairam, M., Sravya, M., Priyadarshini, A., Shubhadarshi, S., & Padhi, D. P. (2024). An Unravelled Potential of Foliar Application of Micro and Beneficial Nutrients in Cereals for Ensuring Food and Nutritional Security. *International Journal of Experimental Research and Review*, *41*(spl.), 19-42. https://doi.org/10.52756/ijerr.2024.v41spl.003.

Reddy, D.M., Lalitha, R., Kannan, S.V., & Raviraj, A. (2021). Effect of different cladding material and mulching on the growth and yield of cucumber (*Cucumis sativus*) under forced ventilated greenhouse system. *International Journal of Environment and Climate Change*, *11*(3), 115-125.

Sairam, M., Maitra, S., Sahoo, U., Sagar, L., & Krishna, T. G. (2023). Evaluation of precision nutrient tools and nutrient optimization in maize (*Zea mays* L.) for enhancement of growth, productivity and nutrient use efficiency. *Research on Crops*, *24*, 666- 77. https://doi.org/10.31830/2348-7542.2023.roc-1016.

Santosh D.T., Maitra, S., & Tiwari, K. (2024b). Enhancing banana production through effective fertigation frequency management and plastic mulch: Impacts on crop growth and yield. *Research on Crops*, *25*(1), 65-72. https://doi.org/10.31830/2348-7542.2024.ROC-1048

Santosh, D. T., Debnath, S., Maitra, S., Sairam, M., Sagar, L., Hossain, A., &Moulick, D. 2024. Alleviation of Climate Catastrophe in Agriculture Through Adoption of Climate-Smart Technologies. In *Climate Crisis: Adaptive Approaches and Sustainability*, pp. 307-332.

Santosh, D.T., & Tiwari, K.N. (2017). Response of tissue cultured banana (*Musa acuminate* L.) cv. Grand Naine to different levels of nutrients under drip fertigation and black plastic mulch. *Applied Ecology and Environmental Research*, *15*(4), 1473-1488. http://dx.doi.org/10.15666/aeer/1504_14731488

Santosh, D.T., Maitra, S., & Tiwari, K.N. (2023). Optimizing nutrients through drip fertigation and plastic mulch on the growth and yield in banana (*Musa acuminata* L.). *Research on Crops*, *24*(2), 330-336. https://doi.org/10.31830/2348-7542.2023.ROC-11163

Sharma, K.K., Chawla, S., & Singh, M.C. (2024). Protected cultivation: Technology, constraints, and its global status. In *Protected Cultivation*, Apple Academic Press, pp. 1-34.

Shukla, C., Acharya, S. K., Bhakar, S.R., & Jamrey, P.K. (2019). Effect of different micro climate on the physiological parameters and yield of capsicum. *Structure*, *1*(34), 66-65. https://doi.org/10.15406/hij.2019.03.00113

Singh, B., Biwalkar, N., & Chhina, R. S. (2020). Response of Sweet Pepper (Capsicum annuum) under Varying Fertigation and Irrigation Applications Grown in Naturally Ventilated Greenhouse. *Journal of Krishi Vigyan*, *8*(2), 236-241.

Soussi, M., Chaibi, M.T., Buchholz, M., &Saghrouni, Z. (2022). Comprehensive review on climate control and cooling systems in greenhouses under hot and arid conditions. *Agronomy*, *12*(3), 626. https://doi.org/10.3390/agronomy12030626

Tezcan, N.Y., Taşpınar, H., & Korkmaz, C. (2023). Effects of shade nets on the microclimate and growth of the tomato. *Journal of Agricultural Sciences*, *29*(2), 443-454. https://doi.org/10.15832/ankutbd.1073156

Thakur, D. S., & Sharma, K. D. (2005). Organic farming for sustainable agriculture and meeting the challenges of food security in 21st century: An economic analysis. *Indian Journal of Agricultural Economics*, *60*(2), 205-219.

Yadav, K., Arora, I., Kumar, A., Rana, M. K., & Kumar, V. (2024). Integrated greenhouse microclimate management: A review. *Journal of Scientific Research and Reports*, *30*(7), 103-114.

Yang, L., Liu, H., Tang, X., & Li, L. 2022. Tomato evapotranspiration, crop coefficient and irrigation water use efficiency in the winter period in a sunken Chinese solar greenhouse. *Water*, *14*(15), 2410.

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