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Effect of microclimate on broccoli (*Brassica oleracea* Var. *Italica*) yield under open field and poly house in Chhattisgarh plain agroclimatic condition

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Abstract

The present investigation entitled “Effect of microclimate on Broccoli (*Brassica Oleracea* Var. *Italica*) yield under open field and poly house in Chhattisgarh plain agroclimatic condition” was undertaken during the rabi season of 2024–25 at the Centre of Excellence on Protected Cultivation and Precision Farming, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). study the effect of microclimate on growth, development, yield and yield attributes of Broccoli (*Brassica oleracea* var. *italica*., varieties Saki and Green Magic) under open field and naturally ventilated polyhouse conditions. The mean weakly air temperature during crop growth period were found to be higher inside the polyhouse (20.7°C) at 7:00 AM and at 2:00 PM it was higher in open field (28.7°C) respectively. Relative humidity was always higher in polyhouse condition as compared to open field. Broccoli grown under open field conditions recorded lower growth and yield: plant height of both varieties Saki and Green Magic (36.82, 34.84 cm plant⁻¹), number of leaves (41,12 leaves plant⁻¹), curd diameter of both varieties (7.5 and 6.9 cm), curd weight (139.4 and 102.2 g plant⁻¹), and curd yield (77.4 and 56.77 q ha⁻¹). While crop grown under polyhouse condition reported enhanced value of these parameters: plant height of both varieties (40.14 and 38.56 cm plant⁻¹), leaves (15 and 14 leaves plant⁻¹), curd diameter of both varieties (8.66 and 8.2 cm), curd weight (180.2 and 130.2 g plant⁻¹) and curd yield (100,72.33q ha⁻¹). In the open field, Saki variety yield decreases when temperature 7:00 AM and 2:00 PM ($r = -0.981^*$, $r = -0.960^*$) and morning light ($r = -0.930$). However, yield increased with relative humidity (RH-I: 0.998**, RH-II: 0.998**) and with light during the afternoon ($r = 0.942$). In the polyhouse, found to be non-significant. Similarly, Green Magic variety in open field broccoli yield decreases when temperature 7:00 AM ($r = -0.997^*$) and morning light intensity ($r = -0.967^*$). However, yield increased with relative humidity (RH- I: 0.984*, RH- II: 0.985*) and with light during the afternoon ($r = 0.975^*$).

Keywords: Broccoli, microclimate, open field, polyhouse, weather parameters

Introduction

Microclimate plays a pivotal role in influencing the growth, development and yield of vegetable crops. It encompasses site specific climatic factors as temperature, humidity, solar radiation, wind speed and soil moisture which are significantly impacting physiological and biochemical processes in plant. Managing microclimate is particularly critical for cool- season vegetable crops like Broccoli, cabbage and beetroot which are sensitive to environmental fluctuations during growth stage. Protected cultivation creates a controlled microclimate by minimizing external stress factors such as excessive rainfall, wind, temperature extremes and pest pressure. This environment often results in improved crop growth, earlier maturity and higher quality produce. In contrast open field cultivation exposes crops directly to the ambient weather, which can be less predictable and more stressful, potentially affecting yield and quality. In protected environment, the natural environment is modified for optimum plant growth, which ultimately provides quality vegetables.

Microclimate modification as per need of the plants is an intended change in the soil-plant atmosphere system, which prevents damage with the aim of attaining higher quality production. The main purpose of protected cultivation is to create a favourable environment for the sustained

growth of plant to realize its maximum potential even in adverse climatic conditions (Job *et al.* 2018) [6]. Broccoli is a nutrient-dense vegetable rich in vitamins, minerals and beneficial compounds, with global production reaching 25.5 million tons in 2023 (FAOSTAT, 2024). High consumption of broccoli has been shown to reduce the risk of cancer because it contains the compound sulforaphane and can also protect against heart diseases (Allen and Allen 2007) [3]. Broccoli is widely grown in China, India, the USA, Spain, Mexico, Italy and other parts of the world. In India, it is commonly grown in the Nigiri Hills, Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir and is often referred to as 'green shoot broccoli' or 'Calabria' or 'Hari gobhi' of the northern plains. India is the second largest producer of broccoli after China. China and India together account for more than 75% of the world's total broccoli production. Broccoli grows best when the average daily temperature is between 17° and 23°C. Temperatures below the optimum range slow down ripening and lead to small buds. In addition, it does not tolerate high temperatures because it produces poor-quality bean sprouts (Anonymous, 2013) [4].

Materials and Methods

This experiment was conducted in a naturally ventilated polyhouse and open field aside the field of the structure of excellence on protected cultivation and precision farming, college of agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur during rabi season 2024 - 25. experimental site is situated at 21°25' N latitude, 81°62' E longitude, and an altitude of 298.15 meters above mean sea level. Microclimatic factors, including temperature (°C), relative humidity (%) and light intensity (Klux), were continuously monitored in both the environments (open field and polyhouse) using Digital hygrometer, multimeter (LM-8000) and light meter (LX-1102) at 07:00 AM and 02:00 PM hours. The experiment was laid out having two growing conditions (*viz.* Poly-house and Open field) with two broccoli varieties (Saki and Green magic) The transplanting of seedlings was accomplished with the spacing of (60 x 30 cm) in both growing conditions (*viz.* Polyhouse and

Open field). Applied fertilizer doses are in NPK ratio of (100:80:100) kg per hectare. Regular cultural practices, crop protection measures were adopted as per the requirements of crops in both growing conditions.

Results and Discussion

The result obtained from the study are briefly presented and discussed in these sections under the heads *viz.*, Weather parameters, growth and development of broccoli. Second aspect studied was yield of broccoli grown under protected environment and open field. The growth and development of broccoli are significantly influenced by various weather parameters including temperature, relative humidity, light intensity, under protected environment and open field conditions. These parameters are fluctuating as per natural process, which may also negatively affect the growth and development of plants. Protected environment, with naturally ventilated polyhouse, helps to cope up with these fluctuations, providing a more stable and favourable microclimate for plant growth & development which ultimately produces higher quantity and better quality.

1. Comparison of the weather parameters for broccoli crops between open field and poly house

Air temperature

Among the climatic factors affecting crop production, temperature is considered very important. It affects growth and development of crops in terms of seed germination, development of economic parts, flowering, pollination, fruit set and quality of produce. The daily air temperature data was recorded at 7.00 AM and 2.00 PM under the polyhouse and open condition during entire growing season of different crops. Data presented in Fig. (1a and b) indicated that with respect to air temperature, there is a clear-cut difference in the result obtained from the open field and the polyhouse. Open field conditions at 7.00AM experienced a highest value of air temperature 22.5°C in the 7th SMW and lowest value of air temperature that was 13.9°C in the 50th SMW.

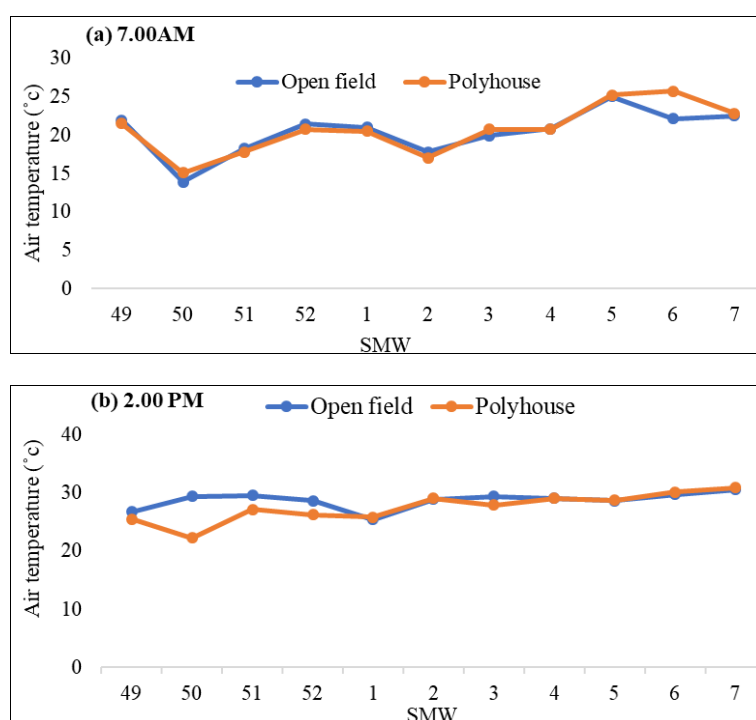


Fig 1(a, b): Average weekly air temperature under polyhouse and open condition

The overall difference in average air temperature between the two environments in 7:00AM was approximately 0.3 °C, with the polyhouse being warmer. Similarly open field conditions at 2:00PM experienced a highest value of air temperature of 30.5 °C in the 7th SMW and lowest value of air temperature was 25.4 °C in the 1st SMW. Average value of air temperature during the crop growing period was 28.7 °C, as compared to those recorded in the polyhouse, which had highest value of air temperature 30.9 °C at the 7th SMW and lower value of air temperature was 22.2 °C at the 50th SMW and the average value of air temperature during crop growing period was 27.5 °C.

Relative humidity

A comparative analysis of relative humidity (RH%) was conducted between open field and polyhouse environments from SMW 49 to SMW 7 at two daily intervals 7:00 AM and 2:00 PM. The data of relative humidity showed in Fig. 2. It is clear from the table that the open field condition recorded the highest and lowest values of relative humidity RH I i.e., 66% at the 52 SMW and 53% at the 7th SMW, respectively and the average value of RHI recorded during crop growing period was 60%.

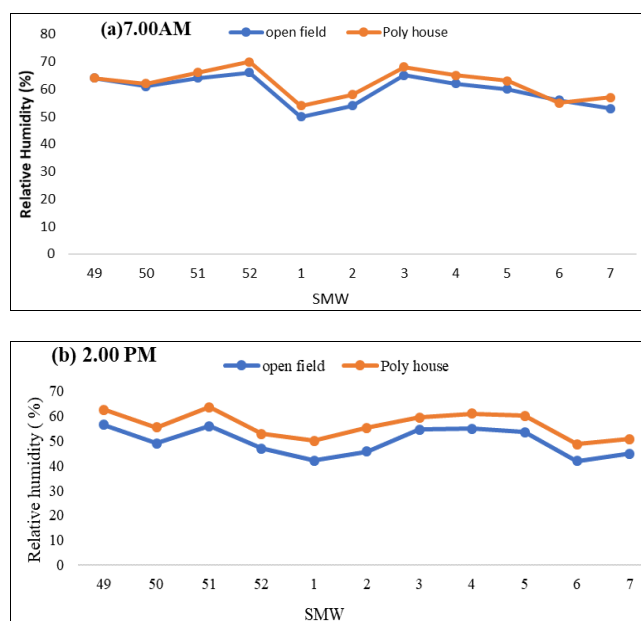


Fig 2(a and b): Average weekly relative humidity (%) under polyhouse and open condition.

The data of relative humidity shown in Fig. 2. It is clear from the table that the open field condition recorded the highest and lowest values of relative humidity (RH I) i.e., 66% at the 52 SMW and 53% at the 7th SMW, respectively and the average value of RH I recorded during crop growing period was 60%. Whereas the highest RH I value recorded in the polyhouse condition was 70% at the 52 SMW, lowest value of RH I recorded 54% at the 1st SMW and the average value was 62%. During the crop growth period, the average weekly RH I inside the polyhouse was 2% higher than in the open field. Similarly, that the open field condition recorded the highest and lowest values of relative humidity (RH II) i.e., 57% at the 49 SMW and 42% at the 1st and 6th SMW, respectively and the average value of RH II recorded during crop growing period was 50%. Whereas the highest RH II value recorded in the polyhouse condition was 64% at the 51 SMW, lowest value of RH II recorded was 49% at the 6th SMW and the average value was 56%. During the crop growth period, the average weekly RH II inside the polyhouse was 6% higher than in the open field.

Relative humidity is higher in the polyhouse because the air movement is less inside, so moisture does not escape easily. Also, water released from soil and plants stays trapped, which increases humidity. Kumari *et al.* (2014)^[7] and Abhivyakti (2013)^[1] also found similar result.

Light intensity

Light intensity is one of the most critical factors affecting plant growth and productivity, especially under protected cultivation systems. The temporal variation in light intensity under polyhouse and open field conditions from the 49th to the 7th Standard Meteorological Week (SMW).

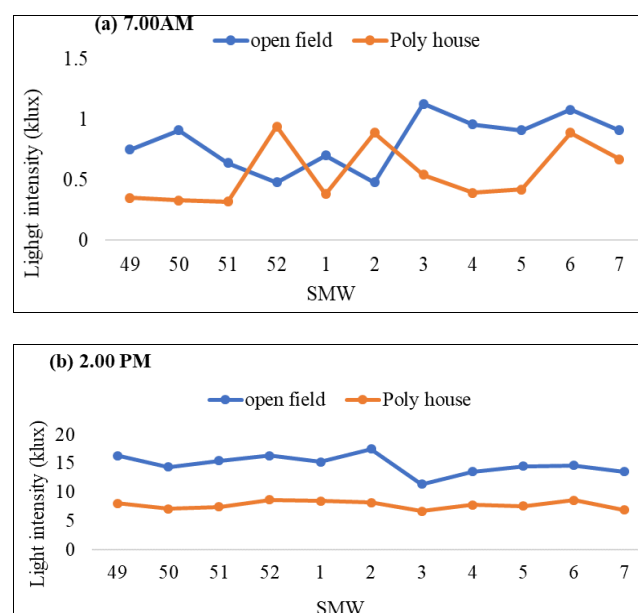


Fig 3(a and b): Average weekly light intensity under polyhouse and open condition.

The observed data is shown in (Fig.3 a and 3 b). The light intensity in open field was recorded in the morning (07:AM) with the highest value of 1.13 (Klux) at the 3rd SMW and lowest value of 0.48 (Klux) at the 52 and 2nd SMW. The average value of morning light intensity in open field was 0.81 (Klux). Whereas the highest light intensity value recorded in the polyhouse condition was 0.94 (Klux) at the 52 SMW and lowest value is 0.32 (Klux) at the 51 SMW. The light intensity in open field was recorded in the afternoon (2:PM) with the highest value of 17.5 (Klux) at the 2nd SMW and lowest value of 11.4 (Klux) at the 3rd SMW. The average value of afternoon light intensity in open field was 14.8 (Klux). Whereas the highest light intensity value recorded in the polyhouse condition was 8.6 (Klux) at the 6th SMW and lowest value is 6.7 (Klux) at the 3rd SMW. This confirms that plants inside the polyhouse consistently received less solar energy which may influence key processes such as photosynthesis, flowering and fruit development. Kumari *et al.* (2014)^[7] also found similar result.

2. Growth and yield of broccoli crop between open field and poly house

2.1 Comparison of plant height for Broccoli variety Saki

Table 1 represent the plant height of Broccoli variety Saki varied between the protected environment and open field conditions across all the growth stages. At early growth stage 15 DAT for the Saki variety, plant growth under the polyhouse were taller, averaging 18.2 cm height, as compared to 16.1 cm height in the open field. At 30DAT the plant height under polyhouse were

slightly higher 29.5 cm, as compare to 28.5 cm height in the open field at 45 DAT, the Saki variety plants grown under the polyhouse were taller, averaging 40 cm height as compare to 36 cm height in the open field. This trend becomes more pronounced over time, with the polyhouse plants reaching 55.5 cm height by 60 DAT, in contrast to 50.5 cm in the open field. At 75 DAT, Saki variety plant grown in the poly house attained an average height of 57.5 cm, which was approximately 4.7% greater than the 53cm recorded under open field. These results are supported by Thapa *et al.* (2013) ^[8] who reported significantly higher plant height in Broccoli under naturally ventilated polyhouse compared to open field.

Table 1: Plant height (cm) of Broccoli varieties under polyhouse and open field.

DAT	Saki			Green Magic		
	Polyhouse	Open Field	Difference	Polyhouse	Open Field	Difference
15	18.2	16.1	2.1	18.8	15.2	3.6
30	29.5	28.5	1.0	28.5	26	2.5
45	40.0	36.0	4.0	38.0	34.0	4.0
60	55.5	50.5	5.0	52.5	47.5	5.0
75	57.5	53.0	4.5	55	51.5	3.5
Mean	40.14	36.82	3.32	38.56	34.84	3.72

DAT = Days after transplanting

2.2 Comparison of plant height for Broccoli variety Green Magic

Table 1 represent the plant height of Broccoli variety Green Magic varied between the protected environment and open field condition across all the growth stages. At early growth stage 15 DAT, the Green Magic varieties growth under the poly house were taller, averaging 18.8 cm height, as compare to 15.2 cm height in the open field. At 30 DAT, the plant height under polyhouse were slightly higher 28.5 cm height, as compared to 26 cm height in the open field. At 45 DAT, the Green Magic variety grown under the polyhouse were taller, averaging 38 cm height as compare to 34 cm height in the open field. This trend becomes more pronounced over time with the poly house plants reaching 52.5 cm height by 60 DAT, in contrast to 47.5 cm in the open field. At 75 DAT, Green Magic variety plant grown in the poly house attained an average height of 55 cm, which was approximately 3.5% greater than the 51.5 cm recorded under open field.

2.3 Comparison of number of leaves per plant for Broccoli variety Saki

Table 2 represents the number of leaves of Broccoli variety Saki varied between the protected environment and open field condition across all the growth stages. At early growth stage 15 DAT, the Saki variety plant growth under the polyhouse with a greater number of leaves, averaging 5 leaves, as compared to 4 leaves in the open field. At 30 DAT the number of leaves under polyhouse were slightly higher 9 leaves, as compare to 8 leaves in the open field at 45 DAT, the Saki variety plants grown under the polyhouse were more, averaging 16 leaves as compare to 13 leaves in the open field. This trend becomes more pronounced over time, with the polyhouse plants reaching 21 leaves by 60 DAT, in contrast to 20 leaves in the open field. At 75 DAT, Saki variety plants grown in the poly house attained an average leaf 23 which was approximately 1% greater than the 22 leaves recorded under open field. These findings suggest that polyhouse conditions provide a favourable environment for leaf development likely due to optimized light and temperature, and

stable humidity. Increased leaf count is closely associated with higher photosynthetic capacity, ultimately supporting curd development and yield. These results are supported by Sam and Rageena (2015) on evaluation of cool season vegetables (Cauliflower and Cabbage) with respect to vegetative and yield parameters under naturally ventilated polyhouse and in open field conditions confirmed maximum number of leaves and shelf life in polyhouse. Similarly, the results are in confirmation with findings of Thapa *et al.* (2013) ^[8] who reported a greater number of leaves under polyhouse than open field in broccoli.

Table 2: Comparison of number of leaves per plant for Broccoli varieties under polyhouse and open field.

DAT	Saki			Green Magic		
	Polyhouse	Open Field	Difference	Polyhouse	Open Field	Difference
15	5	4	1	5	4	1
30	9	8	1	9	7	2
45	16	13	3	14	12	3
60	21	20	1	20	18	2
75	23	22	1	22	19	3
Mean	15	14	1	14	12	3

DAT- Days after transplanting

2.4 Comparison of number of leaves per plant for broccoli variety Green Magic

Table 2 represents the number of leaves of broccoli variety Green Magic varied between the protected environment and open field condition across all the growth stages. At early growth stage 15 DAT, the Green Magic variety plant growth under the polyhouse were a greater number of leaves, averaging 5 leaves, as compared to 4 leaves in the open field. At 30 DAT the number of leaves under polyhouse were slightly higher 9 leaves, as compared to 7 leaves in the open field at 45 DAT, the Green Magic variety plants grown under the polyhouse were more, averaging 14 leaves as compare to 12 leaves in the open field. This trend becomes more pronounced over time, with the polyhouse plants reaching 20 leaves by 60 DAT, in contrast to 18 leaves in the open field. At 75 DAT, Green Magic variety plants grown in the poly house attained an average leaf 22, which was approximately 3% greater than the 19 leaves recorded under open field.

2.5 Comparison of curd diameter for broccoli Varieties

Diameter of curd was recorded at the time of harvesting details regarding curd diameter of broccoli as influenced by the various growing condition of polyhouse and open field. Curd diameter a vital quality and yield parameter which showed marked improvement under polyhouse conditions for both broccoli varieties (Table 3). Saki variety achieved a 15.5% larger curd diameter under polyhouse (8.66 cm) compared to open field (7.50 cm). Green Magic exhibited an even larger differential of 18.8% (8.20 cm vs. 6.90 cm) polyhouse and open field. The broader curd diameter under protected cultivation can be attributed to favourable microclimatic condition balanced temperature and regulated humidity.

Table 3: Comparison of curd diameter (cm) of Broccoli Varieties under polyhouse and open field.

Varieties	Polyhouse	Open Field
Saki	8.66	7.5
Green Magic	8.2	6.9

2.6 Comparison of curd weight plant⁻¹ (g) for broccoli Varieties

The Average curd weight per plant was significantly influenced by the growing environment across both broccoli varieties (Table 4). Polyhouse-grown crops consistently produced higher curd weight compared to open field condition. For the Saki variety, the average curd weight under polyhouse conditions was (180.2 g plant⁻¹), which marked an increase of 29.3% over open field yield (139.4 g plant⁻¹). In the case of Green Magic, polyhouse-grown broccoli yield (130.2 g plant⁻¹), reflecting an increase of 27.4% over the open field average (102.2 g plant⁻¹).

Table 4: Comparison of curd weight plant⁻¹ (g) of Broccoli Varieties under polyhouse and open field.

Variety	Polyhouse	Open Field
Saki	180.2	139.4
Green Magic	130.2	102.2

Joshi *et al.* (2018) and Thapa *et al.* (2013)^[8] reported significant effect of polyhouse conditions on net curd weight 371 g in polyhouse as compared to 294 g in open field conditions.

2.7 Comparison of curd yield (q ha⁻¹) for Broccoli

The yield of broccoli was influenced by the growing environment both (Saki and Green Magic) varieties, as presented in (Table 5). Polyhouse conditions led to a significantly higher yield compared to open field for both Saki and Green Magic. The Saki variety produced a yield of 100.0 qha⁻¹ under polyhouse compared to 77.4 q/ha in open field conditions showing a 29.2% increase in productivity under protected cultivation. similarly, The Green Magic variety followed a similar trend, with a polyhouse yield of 72.33 q/ha compared to 56.77 q/ha in the open field indicating a 27.4% yield advantage under polyhouse.

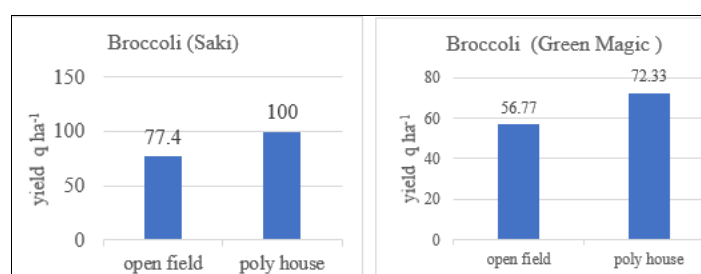


Fig 4: Comparison of curd yield (q ha⁻¹) for broccoli varieties Saki and Green magic

These yield gains under polyhouse conditions may be attributed to the favourable microclimate (controlled temperature, reduced wind velocity, regulated humidity) and enhanced vegetative and reproductive growth (greater plant height, number of leaves and curd size). Additionally, protection from abiotic and biotic stress contributes to improved physiological performance and curd development. Agrawal *et al.* (2003)^[2] in cauliflower, knolkhol and cabbage and Thapa *et al.* (2013)^[8] in broccoli. reported that favourable effect of polyhouse conditions enhanced the growth and yield attributes which ultimately resulted in highest curd yield.

Table 5: Curd yield (q ha⁻¹) of Broccoli Varieties under polyhouse and open field.

Varieties	Polyhouse	Open Field
Saki	100	77.4
Green Magic	72.33	56.77

3. The relationship between weather parameters and yield of Broccoli

3.1 Correlation analysis of broccoli (variety Saki) in open field

In Table 6 the correlation analysis between weather parameters and yield of Saki variety in open field morning and afternoon temperature exhibited a significant negative correlation ($r = -0.981$, $r = -0.960$) indicating that higher morning and afternoon temperatures were consistently associated with reduced yields. RH-I and RH-II exhibited positive correlation ($r = -0.998^{**}$, $r = -0.998$) indicating that higher humidity was highly beneficial for crop performance. maintaining turgor and photosynthetic activity. Morning light intensity was found to have negative correlation ($r = -0.930$) suggesting that high morning light intensity likely related with higher temperatures were detrimental to yield and afternoon light intensity exhibited a positive correlation with yield.

Table 6: Correlation of weather parameters and yield of broccoli (Saki, Green Magic) in open field and poly house.

Weather parameters	Open field		Poly house	
	Saki	Green Magic	Saki	Green Magic
Temp (°C) 7:00 AM.	-0.981*	-0.997*	-0.944	-0.459
Temp (°C) 2:00 PM.	-0.960*	-0.921	-0.909	-0.540
RH-I (%)	0.998**	0.984*	0.887**	0.582
RH- II (%)	0.998**	0.985*	0.911**	0.536
Light intensity 7:00AM	-0.930	-0.967*	-0.814	-0.690
Light intensity 2:00PM	0.942	0.975*	-0.311	0.898

*Significant at 5% level ** significant at 1% level

3.2 Correlation analysis of broccoli (variety Saki) in Poly house

In Table 6 the correlation analysis between weather parameters and yield of Saki variety in Poly house morning and afternoon temperature exhibited a significant negative correlation ($r = -0.944$, $r = -0.909$) with yield. result revealed that elevated thermal conditions during both morning and afternoon periods were consistently associated with reduced yields. RH-I and RH-II showed positive correlation ($r = -0.887^{**}$, $r = -0.911^{**}$) indicating that higher humidity was highly beneficial for crop performance. maintaining turgor and photosynthetic activity. Morning and afternoon light intensity a negative correlation ($r = -0.814$, $r = -0.311$) indicating that high morning light intensity likely related with higher temperature was detrimental to yield.

3.3 Correlation analysis of broccoli (variety Green Magic) in open field

In Table 6 a correlation analysis was carried out between weather parameters and yield of Green Magic variety in open field. A significant negative correlation ($r = -0.997^{*}$, $r = -0.921$) was observed for both morning (7:00 AM) and afternoon (2:00 PM) temperature, this indicates that elevated thermal conditions during both periods were consistently associated with reduced yields. RH-I and RH-II showed a significant positive correlation ($r = -0.984$, $r = -0.985$) with yield. indicating that higher humidity levels were beneficial for crop growth, likely contributing to reduced transpiration stress, and sustained photosynthetic activity. Similarly, Morning light intensity demonstrated a strong negative correlation ($r = -0.967$) with yield and afternoon light intensity a significant positive correlation with yield.

3.4 Correlation analysis of broccoli (variety Green Magic) in Polyhouse

Table 6 provide a detailed correlation analysis between weather parameter and yield of Green Magic variety in Poly house. A significant negative correlation ($r = -0.459$, $r = -0.540$) is observed for both morning (7:00 AM) and afternoon (2:00 PM) temperatures, this indicates that elevated thermal conditions during both periods were consistently associated with reduced yields. Interestingly RH-I and RH-II shows a significant positive correlation ($r = -0.582$, $r = -0.536$) with yield, Morning light intensity remained negatively correlated ($r = -0.690$) with yield. while afternoon light intensity showing significant correlation with yield.

4. Conclusion

The comparison of weather parameters showed that the open field had lower temperatures and humidity but higher light intensity than the polyhouse. For broccoli average air temperature in open field was 20.4°C at 7:00 AM and 28.7°C at 2:00 PM while the air temperature in polyhouse was 20.7°C and 27.5°C at 7:00 AM and 2:00 PM, respectively. RH I and RH II in the open field were 60% and 50%, While in polyhouse it was 62% and 56%, respectively. Light intensity at morning and afternoon was higher in the open field with average of 0.81 klux and 14.8 klux as compared to polyhouse where it was 0.56 klux and 7.8 klux, respectively. The study revealed that polyhouse conditions significantly improved vegetative growth and yield attributes of broccoli as compared to the open field. crop recorded greater plant height, number of leaves, curd size and yield under polyhouse due to favourable microclimatic conditions. Overall, polyhouse cultivation found to be more suitable for leafy and curd-forming crops like broccoli.

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