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Effect of microclimate on yield and yield attributes of cucumber and Knol-Khol in Chhattisgarh plain zone

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Abstract
The study was conducted during the *rabi* season of 2024–25 at the Agricultural Research Farm, College of Agriculture, Raipur (Chhattisgarh Plain Zone), to assess the effect of microclimatic conditions on the growth and yield performance of cucumber (*Cucumis sativus* L., var. Sarita) and knol-khol (*Brassica oleracea* var. *gongylodes*, var. Quick Star) under polyhouse and open-field environments. The objective was to compare crop responses to temperature, humidity, and light intensity and to establish relationships between weather parameters and yield. The results revealed that cucumber grown under polyhouse conditions exhibited superior growth and yield performance compared to open-field cultivation. The total yield under polyhouse was 78.4 t ha^{-1}, more than double that of the open field (36.4 tha^{-1}), owing to the favorable microclimatic environment that enhanced vegetative growth, fruit set and fruit weight. In contrast, knol-khol performed better under open-field conditions, recording a yield of 10.81 t ha^{-1} compared to 9.25 t ha^{-1} under polyhouse, likely due to its adaptability to cooler temperatures and higher light intensity. The findings suggest that protected cultivation is more suitable for cucumber while open-field conditions favorknol-khol, emphasizing the importance of crop-specific microclimate management to optimize productivity.

Keywords: Microclimate, polyhouse, open field, cucumber, Knol-khol, yield

1. Introduction
India is the world's second-largest producer of vegetable. According to the Third Advance Estimates of Horticulture Crops 2023–24 by the Department of Agriculture & Farmers Welfare (DA&FW), India's total vegetable crop covered an area of 11.17 million hectares, produced 205,799 thousand tonnes, and achieved a productivity of 18.42 t/ha. (According to National Horticulture Board. Cucumber was cultivated on approximately 83.2 thousand hectares, yielding 1,274.5 thousand tonnes, resulting in an average productivity of 15.32 t/ha, as reported by (India Stat). As of the 2022–23 period, knol-khol (*Brassica oleracea* var. gongylodes) is cultivated in India across approximately 2.5 thousand hectares, yielding about 50 thousand metric tonnes, resulting in an average productivity of 20 metric tonnes hectare^{-1} (Horticulture Statistics Report 2022–23) [2].

Cucumber (*Cucumis sativus* L.) and knol-khol (*Brassica oleracea var. gongylodes*) are commercially important crops sensitive to environmental fluctuations. Under open-field conditions, extremes of temperature and humidity often reduce growth, fruit set and quality. In contrast, cultivation under polyhouse structures helps maintain favorable microclimatic conditions that enhance photosynthetic activity, promote vegetative growth and improve overall yield and quality (Rajasekar *et al*. 2013) [4]. Moreover, polyhouse systems enable off-season production and efficient resource use addressing the rising demand for fresh vegetables in both domestic and export markets.

Two of the most essential resources for agriculture are land and water. Use of these two precise natural resources needs advance technology to meet out the expanding needs of the world's constantly growing population. The UN (2024) [5] projects that by 2050, there will be over 9.7 billion people on the planet, up from about 8.1 billion in 2024. Pressure on food systems has increased as a result of this population boom, economic growth and changing dietary habits,

especially in emerging countries.

2. Materials and Methods

The experiment was conducted during the winter season of 2024–25 at the Agricultural Research Farm, College of Agriculture, Raipur (21°14′N, 81°38′E, 298.15 m MSL) in the Chhattisgarh plain zone to study the influence of microclimatic conditions on the growth and yield of cucumber (*Cucumis sativus* L., crop variety Sanita) and knol-khol (*Brassica oleracea* var. *gongylodes*, crop variety Quick Star) under polyhouse and open field conditions. The area experiences a tropical wet and dry climate with an average annual rainfall of about 1300 mm. The experimental soil was clay loam to clay in texture and neutral to slightly alkaline in reaction. The experiment was conducted with a spacing of 100 × 50 cm (polyhouse) and 45 × 45 cm (open field) for cucumber, and 30 × 30 cm (polyhouse) and 60 × 30 cm (open field) for knol-khol. Seedlings were raised in protrays containing compostand vermicompost in a 3:1:1 ratio and transplanted after 14 days. The field was prepared with soil, coir pith, and manure in a 2:1:1 ratio, followed by immediate irrigation after transplanting. Recommended fertilizer doses of 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1} for cucumber and 125:60:50 kg $N:P_2O_5:K_2O$ ha^{-1} for knol-khol were applied in three splits using urea, single super phosphate and muriate of potash as nutrient sources. Staking was provided in the polyhouse to support vines and maintain aeration.

Observations on plant growth and yield attributes were recorded from five randomly selected plants in each treatment. For cucumber, data on plant height, leaf area index, days to first flowering, days to first and last harvest, fruit set (%), fruit length, average fruit weight, yield per plant, and total yield were recorded. For knol-khol, observations included plant height, leaf length, days to knob initiation and harvest, knob diameter, knob weight and total yield. Microclimatic parameters *viz*., air and canopy temperature, relative humidity and light intensity were measured at regular intervals using an IR thermometer, digital hygrometer, lux meter, and multimeter under both growing conditions. The Pearson's correlation coefficients were calculated to determine relationships between weather parameters and yield. All analyses were performed at a 5% significance level ($p < 0.05$) using Microsoft Excel.

3. Result

3.1. Growth parameters of cucumber crop

3.1.1. Plant height (cm plant^{-1})

Cucumber plant height increased progressively under both growing conditions, with higher values recorded under polyhouse compared to the open field (Table 1). Mean plant heights in the open field at 15, 30, 45, and 60 DAT were 9.5, 49.0, 155.1, and 203.0 cm, respectively, while in the polyhouse they were 10.6, 126.2, 206.4, and 210.2 cm. Overall, growth was superior under polyhouse conditions due to favorable microclimatic factors such as optimum temperature and relative humidity.

3.1.2 Number of leaves plant^{-1}

The number of leaves per plant of cucumber increased with crop age under both growing conditions, with consistently higher values recorded under polyhouse conditions (Table 1). At 15, 30, 45, and 60 DAT, the mean number of leaves per plant in the open field were 3.8, 5.2, 25.0 and 32.6, respectively, while in the polyhouse they were 5.2, 10.8, 27.0 and 41.2, respectively. The higher leaf production under polyhouse conditions may be attributed to favorable microclimatic conditions such as optimum temperature, humidity, and light intensity, which promoted enhanced vegetative growth.

3.1.3 Leaf area index

The leaf area index (LAI) of cucumber increased progressively under both open field and polyhouse conditions, with distinct differences between the two environments (Table1). In the open field, LAI increased from 1.88 in the first week to a maximum of 2.40 in the eighth week. Under polyhouse conditions, LAI was higher throughout the crop growth period, starting at 2.69 in the first week, peaking at 2.72 in the second week, and remaining above 2.50 until harvest. The consistently higher LAI under polyhouse conditions reflected the favorable microclimatic factors that promoted enhanced canopy development and leaf expansion.

3.1.4 Percent of Fruit Set plant $^{-1}$

The percentage of fruit set per plant in cucumber varied notably between the two growing environments (Table1). In the open field, the number of fruits per plant recorded at 30, 45 and 60 DAT were 3.8, 6.6 and 4.8, respectively. Under polyhouse conditions, the corresponding values were 8.0, 20.6, and 23.8 fruits per plant. The higher fruit set observed under polyhouse conditions indicated that a controlled environment with optimal temperature and humidity, along with protection from abiotic stress, favored enhanced flowering and fruit development compared to the open field.

3.1.5. Length of cucumber (cm fruit^{-1})

The comparative performance of cucumber fruit length under open field and polyhouse conditions at 60, 75, and 90 DAT is presented in Table 1. Under open field conditions, average fruit length was 15.1, 15.8, and 15.2 cm fruit^{-1} at 60, 75, and 90 DAT, respectively. In contrast, polyhouse-grown cucumbers recorded higher fruit lengths of 16.1, 16.4, and 16.5 cm fruit^{-1} at the corresponding harvest stages. Overall, cucumbers grown under polyhouse conditions consistently exhibited greater fruit length than those grown in the open field.

Table 1: Growth parameter of cucumber crop under open field and polyhouse condition

Parameter	Measurement Stage (DAT/Week)	Open Field	Polyhouse
Plant Height (cm plant^{-1})	15 DAT	9.5	10.6
	30 DAT	49.0	126.2
	45 DAT	155.1	206.4
	60 DAT	203.0	210.2
Number of Leaves (plant^{-1})	15 DAT	4	5
	30 DAT	5	11
	45 DAT	25	27
	60 DAT	33	41
Leaf Area Index (LAI)	1st week	1.88	2.69
	8th week	2.40	2.72
Fruit Set (plant^{-1})	60 DAT	4	18
	75 DAT	7	22
	90 DAT	5	23
Fruit Length (cm fruit^{-1})	60 DAT	15.1	16.1
	75 DAT	15.2	16.4
	90 DAT	15.8	16.5

DAT=Days After transplanting

3.2. Yield and Yield attributes of cucumber crop

3.2.1. Average fruit weight fruit^{-1} (g)

The average fruit weight of cucumber under different growing environments is presented in Table 2. Cucumber grown in the

open field recorded a lower average fruit weight of 98.64 g fruit^{-1}, whereas polyhouse-grown cucumbers recorded 124.6 g fruit^{-1}. The higher fruit weight under polyhouse conditions indicates that a controlled environment with stable temperature, higher humidity, and reduced environmental stress favored enhanced fruit growth.

3.2.2. Days to Harvest
The growing environment influenced the harvest duration of cucumber. Open field grown plants required 61 and 71 days to reach first and last harvest, respectively, whereas polyhouse-grown plants reached first and last harvest in 59 and 69 days, indicating faster crop maturity under polyhouse conditions.

3.2.3. Fruit yield kg plant^{-1}
The yield per plant of cucumber at 60, 75, and 90 DAT under different growing environments is presented in Table 2. Open field grown plants produced 0.69, 0.49 and 0.35 kg plant^{-1} at 60, 75, and 90 DAT, respectively, whereas polyhouse-grown plants yielded 2.74, 2.61, and 2.49 kg plant^{-1} at the corresponding stages. Overall, total yield was 1.5 kg plant^{-1}in the open field and 7.85 kg plant^{-1} under polyhouse conditions, demonstrating the positive effect of a controlled microclimate on cucumber growth and productivity.

3.2.4. Yield (kg ha^{-1}) and Area
Cucumber yield under open field (10.13 m²) was 34,100 kg ha^{-1}, 24,360kg ha^{-1}, and 19,484 kg ha^{-1} at 60, 75, and 90 DAT, total yield25.9 tha^{-1}. In the polyhouse (696 m²), yields were 54,824 kg ha^{-1}, 52,332kg ha^{-1} and 49,840 kg ha^{-1}, total yield53.3 tha^{-1}, more than double the open field yield, highlighting the advantage of controlled conditions.

Table 2: Yield and yield attribute of cucumber crop under open field and polyhouse condition

Parameter	Measurement / Stage	Open Field	Polyhouse
Average Fruit Weight (g fruit^{-1})	–	98.64	124.6
Days to Harvest	First harvest (days)	61	59
	Last harvest (days)	71	69
Fruit Yield (kg plant^{-1})	60 DAT	0.69	2.74
	75 DAT	0.49	2.61
	90 DAT	0.35	2.49
Yield per Plot	60 DAT (kg ha^{-1})	34,100	54,824
	75 DAT (kg ha^{-1})	24,360	52,332
	90 DAT (kg ha^{-1})	19,484	49,840
Yield per Unit Area	t/ha	25.9	52.3

3.3. Growth parameters of knol-khol
3.3.1. Plant height (cm plant^{-1})
Plant height differed between growing environments (Table 3). Open field-grown plants reached 7.5, 15.0, 23.4, and 31.0 cm at 15, 30, 45, and 60 DAT, respectively, while polyhouse-grown plants recorded 6.7, 21.4, 22.4, and 27.8 cm. Polyhouse favored early growth, but open field supported greater overall height.

3.3.2. Number of leaves plant^{-1}
Leaf development varied between open field and polyhouse conditions (Table 3). At 15 and 30 DAT, open field plants had 2 and 6leaves plant^{-1}, while polyhouse plants had 3 and 8leaves plant^{-1}, showing early-stage advantage in the polyhouse. At 45 and 60 DAT, open field plants recorded slightly higher leaf numbers (10 and 11) compared to polyhouse plants (8 and 10), indicating more sustained leaf production under open field conditions.

3.3.3. Knob initiation
The timing of knob initiation differed between open field and polyhouse conditions (Table 3). Knol-khol in the open field initiated knob formation at 27 DAT, whereas under polyhouse conditions, knob initiation occurred at 32 DAT. This indicates that knob formation occurred earlier in the open field, likely due to faster transition to the reproductive phase, while the polyhouse environment slightly delayed the process.

3.3.4. Knob diameter (cm knob^{-1})
Knob diameter differed between open field and polyhouse conditions (Table 3). Open field-grown plants recorded a mean knob diameter of 7.36 cmknob^{-1}, whereas polyhouse-grown plants had a smaller diameter of 4.04 cmknob^{-1}, indicating that open field conditions favored larger knob development.

3.4. Yield and yield attributes of knol-khol
3.4.1. Days to harvest
The time to harvest differed between open field and polyhouse conditions (Table 3). Open field-grown plants reached maturity at 50 DAT, whereas polyhouse-grown plants required 54 DAT. This indicates that knol-khol matured earlier in the open field, while the slightly delayed harvest under polyhouse.

3.4.2. Knob weight (g knob^{-1})
Average knob weight differed between open field and polyhouse conditions (Table 3). Open field-grown plants recorded a higher knob weight of 159.5 g knob^{-1}, whereas polyhouse-grown plants had a lower weight of 82.78 g knob^{-1}. This indicates that open field conditions, likely due to greater availability of photosynthetically active radiation, favored better plant growth and higher knob weight.

3.4.3. Total yield (t ha^{-1})
Knol-khol yield under open field (4.5 m²) was 4.87 kg plot^{-1}, equivalent to 1.08 kg m^{-2} or 10.81 t ha^{-1} (Table 3). Under polyhouse conditions (12.6 m²), total plot yield was higher at 11.65 kg plot^{-1}; however, unit area, it was lower at 0.93 kg m^{-2} or 9.25 t ha^{-1}. This indicates open field conditions resulted in higher yield per unit area.

Table 3: Growth parameter, yield and yield attributes of knol-khol under both open field and polyhouse

Parameter	Measurement / Stage	Open Field	Polyhouse
Plant Height (cm plant^{-1})	15 DAT	7.5	6.7
	30 DAT	15.0	21.4
	45 DAT	23.4	22.4
	60 DAT	31.0	27.8
Number of Leaves (plant^{-1})	15 DAT	2	3
	30 DAT	6	8
	45 DAT	9	8
	60 DAT	11	10
Knob Initiation (DAT)	–	27	32
Knob Diameter (cm knob^{-1})	–	7.36	4.04
Days to Harvest (DAT)	–	50	54
Knob Weight (g knob^{-1})	–	159.5	82.78
Total Yield	Plot Yield (kg plot^{-1})	4.87	11.65
	Yield per Unit Area (kg m^{-2})	1.08	0.93
	Yield per Unit Area (t ha^{-1})	10.81	9.25

4. Conclusion

The study demonstrated that microclimatic variations between polyhouse and open-field conditions significantly influenced the growth and yield performance of cucumber (*Cucumis sativus* L.) and knol-khol (*Brassica oleracea* var. *gongylodes*). Cucumber cultivated under polyhouse recorded superior growth and yield attributes, with a mean yield of 53.2 t ha^{-1} compared to 25.9 t ha^{-1} in the open field, owing to the favorable temperature, humidity and light conditions that enhanced photosynthetic efficiency and fruit development. Conversely, knol-khol performed better under open-field conditions, yielding 10.81 t ha^{-1} against 9.25 t ha^{-1} under polyhouse, likely due to its adaptability to lower temperatures and higher light intensity. The results highlight the importance of crop-specific microclimate management, suggesting that protected cultivation is highly beneficial for crops like cucumber, while open-field conditions remain more suitable for temperate crops such as knol-khol.

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