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RESEARCH ARTICLE

Adaptability of exotic crucifers in Indian agro-environments: A comparative study in Hyderabad and Coimbatore

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Abstract

The Brassicaceae (Cruciferae) family comprises many cultivated plants; however, only cabbage and cauliflower are extensively cultivated in India. Numerous crops from this family remain exotic and uncommercialized within the country despite their successful cultivation in other regions. This study evaluates the adaptability of four exotic cole crops; red cabbage, broccoli, Chinese cabbage, and pakchoi grown under polyhouse and open-field conditions in Telangana (Hyderabad) and Tamil Nadu (Coimbatore) to assess their performance across diverse environmental conditions.

The results indicated that head initiation occurred earlier in Hyderabad's open fields, whereas in Coimbatore, all crops except Chinese cabbage were initiated earlier in polyhouses. In Hyderabad, red cabbage reached head maturity sooner under protected conditions, while the other crops matured faster in open fields. In Coimbatore, red cabbage and broccoli matured faster in polyhouses, while the remaining crops were harvested earlier in open fields.

In Hyderabad, broccoli and Chinese cabbage demonstrated superior head attributes in polyhouses, whereas the other crops performed better in open fields. In Coimbatore, all crops showed improved head attributes under polyhouse conditions. In terms of yield, in Hyderabad, red cabbage yielded 7.90 kg and Chinese cabbage 5.15 kg, performing better in open fields, while broccoli and Pakchoi yielded more in polyhouses. In Coimbatore, red cabbage yielded 7.75 kg, broccoli 6.20 kg, Chinese cabbage 6.30 kg, and pakchoi 7.25 kg, all favoring polyhouse cultivation.

This study highlights the potential to increase the commercial viability of exotic crops and enhance food diversity and sustainability in Indian agriculture.

Keywords

cole crops; exotic vegetables; open field; polyhouse

Introduction

India's population has steadily increased over the years. According to recent data, the population in 2024 is 1.44 billion, representing a 0.92% increase from 2023 (World Bank, 2023). Food and nutritional security are critical concerns for the growing population. India has a higher rate of malnourished children than other developing nations, with malnutrition posing a significant challenge. Approximately 50% of children under the age of five (1) are affected by malnutrition, which contributes to nearly one million infant deaths each year and prevents millions from reaching their full potential (2).

India has the highest number of malnourished children globally, with an estimated 400 million children suffering daily (3). The country also faces alarming rates of maternal and newborn mortality linked to malnutrition (4). Among children under five, India is experiencing a severe malnutrition crisis, with over 40 million children stunted and 17 million children wasted (5, 6).

Crop diversification enhances agricultural resilience by improving pest suppression, buffering against climate variability, and increasing productivity across growing conditions (7). Introducing exotic and underutilized vegetables enhances biodiversity, essential for adapting to climate change and preserving soil fertility (8). Exotic crops are rich in essential nutrients, including vitamins, minerals, and plant-based proteins, helping to reduce malnutrition and prevent micronutrient deficiencies (9). These vegetables contribute new nutrient profiles, supporting a more balanced diet and improving nutritional security.

Additionally, exotic vegetables provide farmers with high-income opportunities by targeting niche markets, particularly supermarkets and urban consumers seeking diverse and premium produce. Due to their uniqueness, limited availability, and the growing demand for healthy, nutrient-dense food options, exotic vegetables often command higher market prices (10).

The Brassicaceae (Cruciferae) family is a major angiosperm family within the order Brassicales, comprising 12-15 tribes, 338-360 genera, and 3,709 species, found across all continents except Antarctica (11). This family includes a variety of food plants, such as fodder, oilseeds, vegetables, and condiments. Brassicaceae is a vital source of vitamins A, B1, B2, B6, C, E, K and critical minerals such as magnesium, iron, and calcium. (12). These nutrients are crucial in preventing chronic diseases, such as cardiovascular disorders, diabetes, and certain cancers, which are increasingly prevalent in India. Including Brassicaceae vegetables in the Indian diet can help address nutritional deficiencies and promote better public health outcomes (13).

Brassicaceae is a diverse plant family characterized by cross-shaped flowers and a high glucosinolate content. Glucosinolates play a dual role, acting as toxic compounds and health-promoting agents, as they play important ecological functions in plants. Additionally, glucosinolates play a crucial role in plant defense mechanisms, including allelopathy and protection against various pests and pathogens (14).

In India, however, the cultivation of *Cruciferae* crops is largely limited to cabbage (*Brassica oleracea* var. *capitata*) and cauliflower (*Brassica oleracea* var. *botrytis*). The predominance of these two crops stems from their adaptability to India's diverse agro-climatic zones, particularly in temperate and subtropical regions during the winter season. Moreover, their cultural acceptance of Indian cuisine, strong market demand, and well-developed supply chains make them economically viable for farmers. In contrast, other cruciferous vegetables like broccoli and kale are less widely grown due to limited consumer awareness, higher cultivation requirements, and lower market penetration. While many crops from this family are cultivated in other countries, they remain exotic and largely uncommercialized in India.

The present study evaluates four exotic cole crops (red cabbage, broccoli, Chinese cabbage, pakchoi (Fig.1) grown under polyhouse and open-field conditions in two Indian states, Telangana (Hyderabad) and Tamil Nadu (Coimbatore), to examine their adaptability to these regions. Polyhouse and open-field environments were selected to compare their effects on the growth and performance of exotic crucifer crops. These contrasting conditions were chosen to explore how different cultivation environments influence crop adaptability and yield within India's varied agro-climatic settings. Open-field conditions represent the traditional cultivation method, subject to natural environmental factors such as temperature fluctuations, pests, and unpredictable weather. In contrast, polyhouses provide a controlled environment, offering protection from extreme weather, pests, and diseases while allowing better regulation of temperature, humidity, and light.

This comparative study aims to assess whether exotic crucifers, typically thrive in temperate climates, can perform well under Indian conditions and whether protected cultivation can enhance their adaptability and profitability in Indian agriculture. This study's findings will contribute valuable insights into crop performance under diverse environmental conditions.

Materials and Methods

Planting material

Seeds of red cabbage (*Brassica oleracea var. capitata f. rubra*), broccoli (*Brassica oleracea var. italica*), Chinese cabbage

Fig. 1. Exotic vegetables used in the study.

(*Brassica rapa subsp. pekinensis*), and pakchoi (*Brassica rapa subsp. chinensis*) were sown in pro trays. The seedlings were transplanted into the field 30 days after sowing with 45cm ×45cm spacing for red cabbage, broccoli, and Chinese cabbage and 35 cm × 20 cm spacing (pakchoi).

Experimental field

The soils at the two experimental locations, Coimbatore and Hyderabad, exhibited distinct characteristics that could influence the growth performance of exotic crucifer crops. Coimbatore's red loam soil, with a pH of 8.4 and an electrical conductivity EC (0.64 dS m^{-})^{1}, demonstrated low availability of nitrogen but high levels of phosphorus and potassium. In contrast, Hyderabad's red sandy soil had a lower pH of 7.3 and a higher EC (0.84 dS m^{-1}), with similarly low nitrogen availability and high phosphorus and potassium contents. These soil differences, particularly in nutrient availability and pH, are critical for assessing crucifer crops' adaptability and yield potential under open and protected cultivation in these agro-environments. Detailed weather data for both locations, under open field and polyhouse conditions, are presented in Tables 1 and 2, respectively. The experiment was conducted at Ethereal DNA Pvt. Ltd. farm, Hyderabad, and the Orchard, HC&RI, Tamil Nadu Agricultural University (TNAU), Coimbatore, from November 2024 to March 2024 under open field and protected conditions.

Observation recorded

In the experiments, five plants were randomly selected from each replication of all treatments to record observations. The parameters recorded at harvest included plant height (cm), number of leaves per plant, number of days to head initiation, number of days to harvest, head length, head width, head weight, and crop yield per plot.

Table 1. Weather data for Hyderabad under open field and polyhouse conditions

Month	Temperature				Relative humidity		Wind speed (kmph)		Rainfall (mm)
	Protected		Open		Protected	Open			
	Max	Min	Max	Min	Max	Max	Max	Min	
November	33.0	22.9	30.0	21.0	98.1	94.7	6.7	2.3	101.8
December	33.0	22.2	28.9	18.3	97.5	95.8	9.1	1.7	46.0
January	32.5	21.5	29.2	18.0	98.3	93.4	7.8	3.0	26.0
February	35.5	22.0	32.9	19.0	91.4	87.3	10.1	3.5	0.0
March	37.0	23.6	35.6	21.5	87.6	83.5	8.4	2.7	0.0
April	39.4	26.5	37.8	24.5	84.2	81.6	8.3	2.6	0.0

Table 2. Weather data for Coimbatore under open field and polyhouse conditions

Month	Temperature (°C)				Relative humidity (%)		Wind speed (kmph)	Rainfall (mm)
	Protected		Open		Protected	Open		
	Max	Min	Max	Min	Max	Max	Max	
November	30.4	20.9	28.10	18.40	88.10	85.00	6.00	100.00
December	32.6	18.1	26.30	15.60	83.60	80.00	6.00	50.00
January	30.3	16. 9	27.80	14.50	87.20	84.00	6.00	08.00
February	34.4	18 .5	30.90	16.20	81.20	78.00	7.00	10.00
March	36.9	23.7	34.50	20.10	77.50	74.00	8.00	20.00
April	39.5	25.1	37.90	23.30	71.40	69.00	9.00	28.00

Statistical analysis

The study was laid out in a two-factorial randomized block design (FRBD). Analysis was conducted using GRAPES software, version 1.1.0, with statistical significance evaluated at the 5% level ($p < 0.05$) through ANOVA.

Results

Plant height

In Hyderabad, the maximum plant height for broccoli was recorded at 46.20 cm under protected conditions, followed by Chinese cabbage at 26.80 cm. In open field conditions, broccoli exhibited the highest plant height (39.00 cm), followed by red cabbage (31.41 cm).

In Coimbatore, broccoli also showed the highest plant height under protected conditions (43.40 cm), followed by red cabbage (30.90 cm). In open field conditions, broccoli again recorded the highest plant height (37.00 cm), while red cabbage reached 25.10 cm.

Red and Chinese cabbage in Hyderabad exhibited better plant height under open field conditions than polyhouse cultivation. Conversely, in Coimbatore, all four crops demonstrated superior plant height under protected conditions compared to the open field environment. The higher plant heights observed in red cabbage, broccoli, Chinese cabbage, and pakchoi under protected conditions in Coimbatore can be attributed to the controlled environment provided by the polyhouse. Under protected conditions, temperature fluctuations are minimized, and relative humidity is higher than in the open field. This consistent humidity reduces plant stress and ensures better moisture availability. The polyhouse shields crops from wind, rain, and direct sun exposure, creating a stable microclimate. Additionally, the even light diffusion inside the polyhouse supports more efficient photosynthesis. The amalgamation of these factors led to increased plant heights in sheltered environments relative to open fields (Fig. 2, Table 3).

For instance, broccoli significantly differs from red cabbage, Chinese cabbage, and pakchoi. The analysis reveals that protected conditions in Coimbatore are substantially different from all other conditions. Additionally, results demonstrate that the interaction between factors A and B substantially influences broccoli's plant height under protected conditions in Hyderabad.

Number of leaves

In Hyderabad, the highest number of leaves was recorded in broccoli (20.70), followed by pakchoi (17.00) under protected conditions. In the open field, broccoli had the highest number of leaves (17.40), while pakchoi had 13.80. In Coimbatore, pakchoi had the highest number of leaves under protected conditions, with a count of 18.80, followed by broccoli (17.70). In the open field, pakchoi recorded 14.30 leaves, while broccoli had a slightly higher count of 14.40 leaves (Table 3).

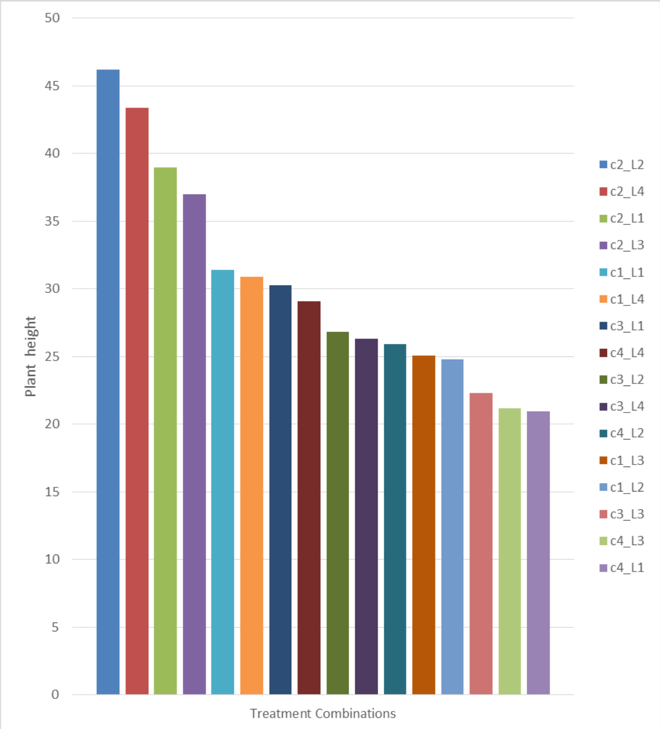

Fig. 2. Plant height of different exotic vegetables.

C1-Red Cabbage; C2-Broccoli; C3-Chinese Cabbage; C4-Pakchoi
L1-Hyderabad Open Field; L2-Hyderabad Polyhouse; L3-Coimbatore Open Field; L4-Coimbatore Polyhouse

For the number of leaves, broccoli exhibits a significant difference compared to red cabbage, Chinese cabbage, and pakchoi. The analysis shows that Coimbatore leaves under protected conditions are significantly higher than in all other conditions. Additionally, the results reveal that the interaction between factors A and B significantly affects the number of leaves in broccoli grown under protected conditions in Hyderabad.

Number of days to head initiation

In Hyderabad, broccoli took the longest to initiate heads under protected conditions, at 59.5 days, followed by red cabbage at 58.5 days. In the open field, broccoli took an average of 50.9 days to initiate heads, while red cabbage had a slightly shorter growth period, with an average of 49.9 days (Table 4).

In Coimbatore, Chinese cabbage took 44.9 days to initiate heads, followed by red cabbage at 53.5 days under protected conditions. Chinese and red cabbage initiated heads in the open field after 41.0 and 57.1 days, respectively. There was a significant difference between the crops between conditions, and the interaction between factors A and B also showed Statistical significance.

Days to harvest

In Hyderabad, broccoli was harvested in 73.2 days under protected conditions, followed by pakchoi at 30.3 days. In the open field, red cabbage required an average of 81.8 days to reach the harvest stage, while broccoli took an average of 72.6 days.

In Coimbatore, red cabbage was harvested in 74.4 days under protected conditions, followed by pakchoi at 29.6 days. In the open field, red cabbage required 78.4 days to reach harvest, while broccoli took 66.7 days (Table 4).

For days to harvest, Factor A (crops) showed a significant difference, whereas Factor B (conditions) and the interaction between Factors A and B did not show a significant difference.

Table 3. Plant height (cm) and number of leaves as influenced by growing conditions and environments in different exotic vegetables

Crop	Plant height (cm)						No. of leaves					
	Hyderabad			Coimbatore			Hyderabad			Coimbatore		
	Open (L1)	Protected (L2)	Mean	Open (L3)	Protected (L4)	Mean	Open (L1)	Protected (L2)	Mean	Open(L3)	Protected (L4)	Mean
Red cabbage (C1)	31.41	24.81	28.11	25.10	30.90	28.00	13.22	8.50	10.86	8.00	10.500	9.25
Broccoli (C2)	39.00	46.20	42.60	37.00	43.40	40.20	17.40	20.70	19.05	14.40	17.70	16.05
Chinese Cabbage (C3)	30.30	26.80	28.55	22.30	26.30	24.30	10.90	8.48	9.69	10.40	9.50	9.95
Pakchoi (C4)	20.95	25.90	23.42	21.20	29.10	25.15	13.80	17.00	15.40	14.30	18.80	16.55
	SE(d)			CD (0.05%)			SE(d)			CD (0.05%)		
Factor-A	0.548			1.168			0.29			0.618		
Factor-B	0.548			1.168			0.29			0.618		
A×B	1.096			2.337			0.58			1.236		

Factor-A (crops), Factor-B (conditions)

Table 4. Days taken for head initiation and head harvest in different exotic vegetables

Crop	Days taken for head initiation						Days taken for head harvest					
	Hyderabad			Coimbatore			Hyderabad			Coimbatore		
	Open (L1)	Protected (L2)	Mean	Open (L3)	Protected (L4)	Mean	Open (L1)	Protected (L2)	Mean	Open(L3)	Protected (L4)	Mean
Red cabbage(C1)	49.9	58.5	54.2	57.1	53.5	55.3	81.8	78.3	80.0	78.4	74.4	76.4
Broccoli(C2)	50.9	59.5	55.2	54.5	54.1	54.3	72.6	73.2	72.9	66.7	66.5	66.6
Chinese cab-	41.9	44.3	43.1	41.0	44.9	42.9	54.6	56.4	55.5	53.2	57.7	55.4
Pakchoi(C4)	17.5	18.1	17.8	16.2	16.1	16.1	28.5	30.3	29.4	27.5	29.6	28.5
	SE(d)			CD (0.05%)			SE(d)			CD (0.05%)		
Factor-A	0.499			1.063			5.159			10.995		
Factor-B	0.499			1.063			5.159			10.995		
A×B	0.997			2.125			10.317			21.985		

Factor-A (crops), Factor-B (conditions)

Head length

In Hyderabad, pakchoi's maximum head length was 14.94 cm, while broccoli had a head length of 12.72 cm under protected conditions. In the open field, Chinese cabbage had the longest head, measuring 13.16 cm, followed by pakchoi (12.72 cm).

In Coimbatore, the maximum head length of pakchoi was 15.5 cm, while Chinese cabbage had a head length of 13.88 cm under protected conditions. Pakchoi had the longest head in the open field, measuring 11.44 cm (Table 5).

The head length of pakchoi demonstrated a statistically significant difference when compared to broccoli, red cabbage, and Chinese cabbage. Analysis revealed that the protected condition in Coimbatore resulted in a markedly greater head length than all other conditions. Furthermore, a significant interaction effect between (Factor A) and (Factor B) was observed, indicating that the combined influence of these factors significantly impacted the head length of pakchoi grown under protected environments in Coimbatore and Hyderabad.

Head width

In Hyderabad, the maximum head width of red cabbage was recorded as 10.55 cm, while broccoli had a head width of 10.49 cm under protected conditions. In the open field, red cabbage exhibited the highest width measurement (10.55 cm), while Chinese cabbage had a slightly smaller width of 9.32 cm.

In Coimbatore, the maximum head width was observed in red cabbage at 12.06 cm, followed by broccoli at 11.58 cm under protected conditions. In the open field, broccoli exhibited the widest head, measuring 9.62 cm, whereas the cabbage variety had a slightly narrower head, measuring 8.44 cm (Table 5).

The analysis indicates that the head width of red cabbage differs significantly from that of broccoli, Chinese cabbage, and pakchoi. Furthermore, the results show a significant effect of the protected condition in Coimbatore, with head width values markedly higher than those observed under other conditions. The interaction between (factor A) and (factor B) significantly influences the head width of red cabbage grown in Coimbatore under protected conditions.

Head weight

In Hyderabad, pakchoi's maximum head weight was 317.27 g, while broccoli had a head weight of 301.27 g under protected conditions. In the open field, red cabbage exhibited the highest head weight, measuring 399.59 g, while broccoli had a slightly lower head weight of 281.13 g.

In Coimbatore, the maximum head weight of Chinese cabbage was observed to be 301.45 g, while broccoli had a head weight of 300.30 g under protected conditions. In the

Table 5. Head length and head width in different exotic vegetables

Crop	Length of the head						Width of the head					
	Hyderabad			Coimbatore			Hyderabad			Coimbatore		
	Open (L1)	Protected (L2)	Mean	Open(L3)	Protected (L4)	Mean	Open (L1)	Protected (L2)	Mean	Open(L3)	Protected (L4)	Mean
Red cabbage(C1)	9.79	8.38	9.085	7.94	10.31	9.125	10.55	10.10	10.32	8.44	12.06	10.25
Broccoli(C2)	10.92	12.72	11.82	10.38	13.52	11.95	8.06	10.49	9.27	9.62	11.58	10.60
Chinese cab-	13.16	9.61	11.35	10.98	13.88	12.43	9.32	8.49	8.90	8.66	10.83	9.74
Pakchoi(C4)	12.72	14.94	13.83	11.44	15.5	13.47	3.81	4.31	4.06	3.84	4.89	4.36
	SE(d)			CD (0.05%)			SE(d)			CD (0.05%)		
Factor-A	0.235			0.501			0.185			0.394		
Factor-B	0.235			0.501			0.185			0.394		
A×B	0.47			1.001			0.37			0.788		

Factor-A (crops), Factor-B (conditions)

open field, red cabbage had the highest head weight of 314.40 g, while broccoli had a slightly lower head weight of 272.64 g (Fig. 3 and Table 6).

The analysis of head weight among the four cole crops—red cabbage, broccoli, Chinese cabbage, and pakchoi—reveals significant differences. Red cabbage, in particular, shows a significantly higher head weight than the other crops. Protected cultivation in Hyderabad and Coimbatore exhibits similar results, with no statistically significant difference between the two locations under protected conditions. However, both locations outperform open-field cultivation in terms of head weight. Moreover, a significant interaction effect between Factor A (crops) and Factor B (conditions) was observed, particularly for red cabbage cultivated in Hyderabad under open field conditions, where head weight was notably influenced.

Yield per plot (2.5 x 2.5 m)

In Hyderabad, under protected conditions, the highest yield per plot (7.65 kg) was observed for pakchoi, followed by broccoli (6.35 kg). In the open field, red cabbage had the highest yield (7.90 kg), followed by pakchoi (6.30 kg).

In Coimbatore, the maximum yield per plot was recorded for pakchoi (7.25 kg) under protected conditions, followed by Chinese cabbage (6.30 kg). In the open field, red cabbage had the highest yield (7.10 kg), closely followed by pakchoi, which yielded 6.10 kg (Fig. 4 and Table 6). The results under protected conditions were significantly superior to those under open-field conditions. Red cabbage exhibited significantly higher yields than the other cole crops, while Chinese cabbage yielded significantly less. Furthermore, protected cultivation consistently resulted in significantly better yields than open field conditions, with Coimbatore's protected environment yielding the highest levels of statistical significance. The interaction between crop type and growing conditions was statistically significant; red cabbage grown in the open field of Hyderabad produced the highest yield, closely followed by red cabbage in Coimbatore under protected conditions and Chinese cabbage in Hyderabad under protected conditions, both of which demonstrated yields that were statistically comparable to one another.

Discussion

The controlled environment provided by the polyhouse resulted in the superior overall performance of the tested vegetables compared to the open field environment, consistent with previous studies' findings (15,16). Polyhouses create a favorable microclimate by regulating temperature, humidity, and light, boosting key metabolic activities like photosynthesis and respiration and ultimately enhancing plant growth and yield.

For instance, previous research has shown that Sweet Pepper Volante achieved better growth, yield, and quality when grown in a naturally ventilated polyhouse (17). The study found that capsicum plants had greater growth and yield in polyhouse conditions compared to the open field, with maximum height (65 cm), fruit weight (60 g), rind thickness (0.91 cm), and yield per plant (2.28 kg) observed in the polyhouse. Overall yield per hectare was also higher in the polyhouse (50.66 t/ha) than in the open field (20.10 t/ha). Additionally, water use efficiency was greatest in the polyhouse at 21.22 kg/m^3. Our results align with this, as crops grown under polyhouse conditions showed superior growth and exhibited efficient water utilization, especially when compared to the open field (18).

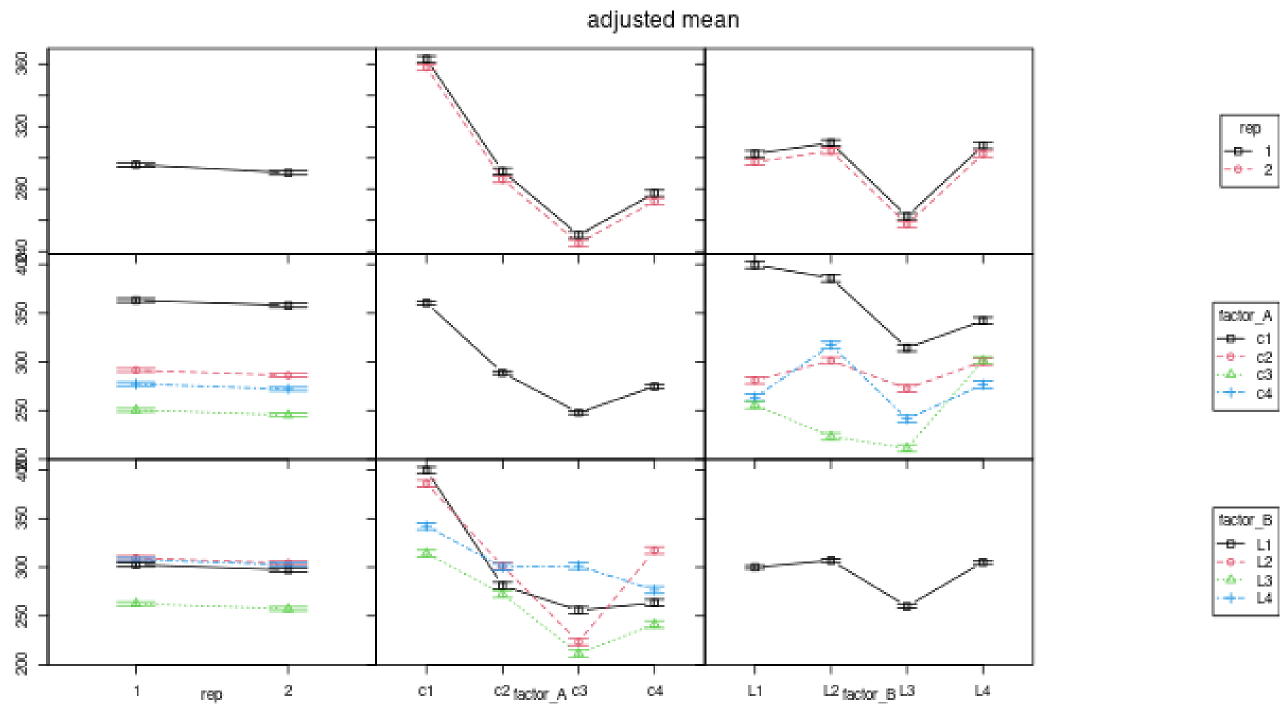

Fig. 3. Head weight of different exotic vegetables.

C1-Red Cabbage; C2-Broccoli; C3-Chinese Cabbage; C4-Pakchoi
L1-Hyderabad Open Field; L2-Hyderabad Polyhouse; L3-Coimbatore Open Field; L4-Coimbatore Polyhouse

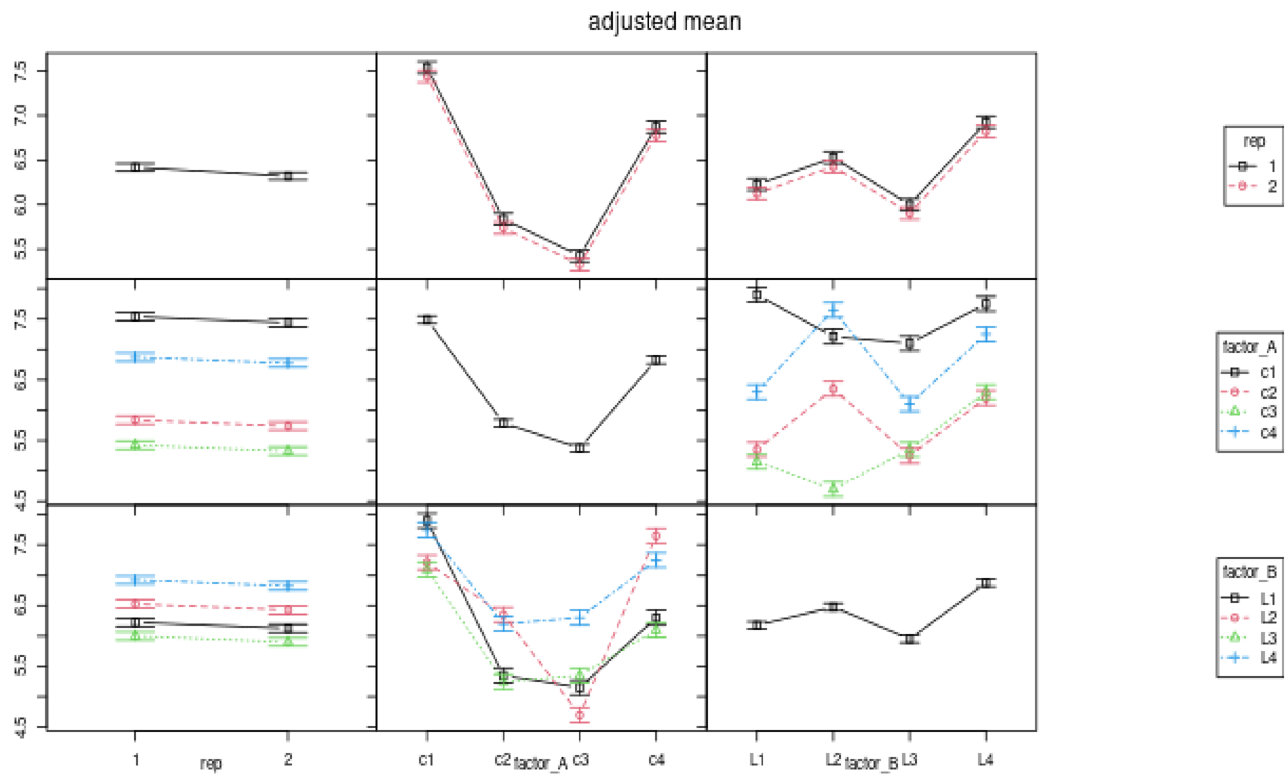

Fig. 4. Yield per plot (2.5 mx 2.5 m) of different exotic vegetables.

C1-Red Cabbage; C2-Broccoli; C3-Chinese Cabbage; C4-Pakchoi
L1-Hyderabad Open Field; L2-Hyderabad Polyhouse; L3-Coimbatore Open Field; L4-Coimbatore Polyhouse

Moreover, the influence of polyhouses on head formation in vegetables such as broccoli and Chinese cabbage was noteworthy. The naturally ventilated polyhouse (NVPH) used in other studies produced the largest head diameters, heaviest head weights, and highest marketable yields (9). Our results reflected a similar trend, with playhouse-grown crops achieving larger head sizes and greater weights than their open-field counterparts. The shorter head initiation period and faster head development in open fields may be linked to higher light intensity and fluctuating temperatures. Still, these conditions often lead to lower overall yields and compromised quality compared to the stable polyhouse environment (19).

Protected cultivation structures significantly conserve solar energy and raise the internal temperature. As a result of this elevated temperature, the reference crop evapotranspiration changes in relation to both temperature and radiation levels (20). Furthermore, crops like cucumber, tomato, and capsicum have been identified as highly profitable under polyhouse conditions, primarily due to their ability to maximize yield potential in a controlled environment (21). While our study focused on leafy vegetables, the principle holds true, as we observed significant yield improvements across all tested crops. The results showed that protected cultivation structures yielded significantly more than open field conditions for all tested vegetables (22).

In conclusion, the study highlights the benefits of protected cultivation, specifically through polyhouse systems, compared to open field conditions for various cole crops. The controlled environment of polyhouses significantly enhances plant growth and yield while promoting water efficiency and safeguarding crops from adverse weather events. These findings are particularly relevant for optimizing vegetable production in regions experiencing climate variability and

Table 6. Crop yield per plot (2.5 m x 2.5 m) and yield attributing characters in different exotic vegetables

Crop	Weight of the head						Crop yield per plot					
	Hyderabad			Coimbatore			Hyderabad			Coimbatore		
	Open (L1)	Protected (L2)	Mean	Open(L3)	Protected (L4)	Mean	Open (L1)	Protected (L2)	Mean	Open(L3)	Protected (L4)	Mean
Red cabbage	399.59	386.04	392.81	314.40	342.31	328.35	7.90	7.21	7.55	7.10	7.75	7.42
Broccoli(C2)	281.13	301.27	291.20	272.64	300.30	286.47	5.35	6.35	5.85	5.25	6.20	5.72
Chinese cabbage(C3)	255.68	223.40	239.54	211.40	301.45	256.42	5.15	4.70	4.92	5.35	6.30	5.82
Pakchoi(C4)	263.52	317.27	290.39	241.41	276.73	259.07	6.30	7.65	6.97	6.10	7.25	6.67
	SE(d)			CD (0.05%)			SE(d)			CD (0.05%)		
Factor-A	2.541			5.416			0.086			0.183		
Factor-B	2.541			5.416			0.086			0.183		
A×B	5.082			10.832			0.172			0.366		

Factor-A (crops), **Factor-B** (conditions) water scarcity. Future research should focus on the long-term sustainability of polyhouse cultivation, examining economic viability, potential impacts on soil health, and the adaptability of various crops to these controlled environments. Such investigations could provide valuable insights for farmers and agricultural policymakers aiming to improve productivity and resilience in vegetable farming.

Conclusion

In conclusion, red cabbage achieved the highest yield in the open field condition in Hyderabad. Under protected cultivation, red cabbage in Coimbatore recorded the highest yield, closely followed by Chinese cabbage in Hyderabad. Chinese cabbage in Coimbatore and red cabbage in Hyderabad under protected conditions also performed well, demonstrating the effectiveness of polyhouse systems in enhancing yields across crops and locations. These results highlight the advantages of protected cultivation for optimizing vegetable productivity. Polyhouse cultivation represents a significant advancement in vegetable production, offering a more controlled and efficient alternative to open-field farming. By mitigating the limitations of open-field agriculture, polyhouses contribute to improved yields, enhanced crop quality, and increased resource-use efficiency.

While challenges remain, the benefits of polyhouse cultivation make it a promising approach for sustainably meeting the growing demand for high-quality vegetables. The increasing demand for sustainable agricultural techniques indicates a bright future for polyhouse production. Advancements in technology, including climate control systems, hydroponics, and smart farming techniques, can substantially increase resource efficiency, reduce environmental impact, and enhance crop yields in polyhouse agriculture. These advances provide an effective means of adapting to fluctuating climatic conditions, making polyhouse farming a feasible approach for improving food security and promoting agricultural sustainability across various agro-environments

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Authors' contributions

PL wrote the original draft and collected resources. BKS conceptualized the study, composition & editing, supervision, validation, and resources. CIR, KV, GAK carried out the visualization process. KI performed statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

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Declaration of generative AI and AI-assisted technologies in the writing process

While preparing this work, the authors used Grammarly and ChatGPT 4o mini to improve language and readability. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the publication's content.

References

1. Kinikar A, Khadse S, Valvi C, Kulkarni R, Bichkar V. " Magic Potion" to tackle India's silent crisis: Severe acute malnutrition in children.Pediatrics.2015;135(Suppl 1):S4-5. https://doi.org/10.1542/peds.2014-3330G
2. Bagilkar VV, Savadatti BB. A descriptive study on malnutrition. Asian J Nurs Educ Res. 2015;5(1):72-77.https://doi.org/10.5958/2349-2996.2015.00016.6
3. Hazel DE, Ladd EC, Begre A. Childhood malnutrition in India. In: Breaky S, Corles IB, Meedzan NL, Nicholas PK, editors. Global Health Nursing in the 21st Century. New York: Springer Publishing Company, LLC; 2015. p. 281–305.
4. Barla PK. A situation analysis on malnutrition by food-intake practices: link to maternal and child mortality in India. Int J Community Med Public Health. 2023;10(1):502-510.https://doi.org/10.18203/2394-6040.ijcmph20223581.
5. Ravi S, Singh R. Nutrition in India: Targeting the first 1000 days of a child's life . SSRN *3041157*; October21,2 016. Availablefrom: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3041157. https://doi.org/10.2139/ssrn.3041157
6. Avula R, Raykar N, Menon P, Laxminarayan R. Reducing stunting in India: what investments are needed? Matern Child Nutr. 2016;12(Suppl 1):249-252.https://doi.org/10.1111/mcn.12291
7. Lin BB. Resilience in agriculture through crop diversification: adaptive management for environmental change. BioScience. 2011;61(3):183-93. https://doi.org/10.1525/bio.2011.61.3.4
8. Frison EA, Cherfas J, Hodgkin T. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. Sustainability. 2011;3(1):238-53. https://doi.org/10.3390/su3010238
9. Shraddha, Bhardwaj RK, Shukla YR, Akshay DA, Vashishat RK. Underexploited tropical and subtropical vegetable crops for diversification and nutritional security: a review. Agroecology and Sustainable Food Systems. 2024;48(8):1094-1114.https://doi.org/10.1080/21683565.2024.2348638
10. Silva Dias J. World importance, marketing and trading of vegetables. Acta Hortic. 2011;921:153–69.https://doi.org/10.17660/ActaHortic.2011.921.1.
11. Narayan S, Ibrahim A, Khan FA, Hussain K, Malik AA, Mir SA, Narayan R. Organic nutrient management for improved plant growth and head yield of Chinese cabbage (*Brassica rapa* L. var *pekinensis*). Int J Curr Microbiol App Sci. 2018;7(9):3049-59. https://doi.org/10.20546/ijcmas.2018.709.380
12. Appel O, Al-Shehbaz IA. Cruciferae. In: Kubitzki K, Bayer C, editors. Flowering Plants: Dicotyledons. The Families and Genera of Vascular Plants, vol 5. Berlin, Heidelberg: Springer; 2003. p. 75–174. https://doi.org/10.1007/978-3-662-07255-4_17
13. Jahangir M, Kim HK, Choi YH, Verpoorte R. Health‐affecting compounds in Brassicaceae. Compr Rev Food Sci Food Saf. 2009;8(2):31-43. https://doi.org/10.1111/j.1541-

4337.2008.00065.x

14. Raiola A, Errico A, Petruk G, Monti DM, Barone A, Rigano MM. Bioactive compounds in Brassicaceae vegetables with a role in the prevention of chronic diseases. Molecules. 2017;23(1):15. https://doi.org/10.3390/molecules23010015
15. Abegunrin TP, Ojo OI, Lasisi MO. Assessment of the performance of drip-irrigated green pepper (*Capsicum annum* L.) under poly-house and open-field conditions. Asian J Adv Agric Res. 2024;24 (1):1-0. https://doi.org/10.9734/ajaar/2024/v24i1482
16. Thapa U, Rai R, Lyngdoh YA, Chattopadhyay SB, Prasad PH. Assessment of producing quality sprouting Broccoli (*Brassica oleracea* var. *italica*) under cover and open condition. Afr J Agric Res. 2013;8(15):1315-18. https://doi.org/10.5897/AJAR12.2115
17. Rathore R, Bahadur V. Assessment of capsicum (*Capsicum annuum*) varietal performance in natural ventilation polyhouse settings. Int J Environ Clim Change. 2024;14(2):128-34. https://doi.org/10.9734/ijecc/2024/v14i23929
18. Manjunatha MK, Babu BM, Ramesh G, Reddy GVS, Kulkarani PS. Comparative analysis of capsicum cultivation under different protected structures. Int J Plant Soil Sci. 2023;35(23):572-78. https://doi.org/10.9734/ijpss/2023/v35i234275.
19. Babu MR, Reddy RVSK. Studies on performance of sprouting Broccoli (*Brassica oleracea* var. *italica*) under different growing conditions. Journal of Eco-friendly Agriculture. 2017;12(2):44-46.
20. Santosh DT, Tiwari KN, Singh VK. Influence of different protected cultivation structures on water requirements of winter vegetables. Int J Agric Environ Biotechnol. 2017;10(1):93-103. https://doi.org/10.5958/2230-732X.2017.00004.3
21. Rani N, Tiwari D, Kaur G, Sharma D. Enhancing agricultural productivity: A comparative study of vegetable cultivation under polyhouse and open field conditions in Punjab, India. J Sci Res Rep. 2024;30(7):166-74. https://doi.org/10.9734/jsrr/2024/v30i72133
22. Pandey V, Ranjan R, Pandey H, Rawal J, Bala M. Performance of different cole crops in different growing environmental conditions under mid hills of Uttarakhand. Prog Hort. 2020;52 (2):185-92. https://doi.org/10.5958/2249-5258.2020.00027.5