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Effect of Environmental Variations Influence on Plant Growth in Different Protective Structures and Growing Mediums

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ABSTRACT

Spinach (*Spinacia oleracea* L.), renowned for its nutritional content and health benefits, is widely cultivated worldwide. Traditional farming faces challenges such as heavy rain, thunderstorms, excessive solar radiation, and uncertain climates, making it difficult to feed the global population. Protected cultivation, employing structures like greenhouses, shields crop from adverse weather, ensuring stable yields. This research investigates how environmental variations influence plant growth in different protective structures and growing mediums. Experiment sites include open field, polyhouse, and net house environments, chosen for their diverse conditions. Various media, such as garden soil, cocopeat, and a blend of both, are used to fill earthen pots. Semi-savoy spinach seeds are sourced from the local market and soaked for 24 hrs before planting. The dibbling method ensures consistent seed spacing in pots. Environmental parameters like temperature, humidity, and light intensity are monitored regularly using instruments like thermometers and lux meters. Plant height, leaf quantity, and yield are measured to assess growth and productivity. After harvesting, the shoot portion is dried in an oven to determine dry weight, providing insights into yield. Data collection includes observations from different climate scenarios to evaluate the impact on plant characteristics. This comprehensive approach aims to understand how protective structures and growing mediums interact with environmental conditions to affect plant growth, offering valuable insights for agricultural practices and crop management strategies.

Keywords Temperature, Relative humidity, Light intensity, Polyhouse, Net house, Coco peat.

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INTRODUCTION

Worldwide, spinach (*Spinacia oleracea* L.), a green crop valued for its nutritional content and health advantages, is widely grown. Feeding the entire world population through traditional farming is challenging. Open field cultivation faces significant constraints due to heavy rain, thunderstorms, excessive solar radiation, and uncertain climates (Max *et al.* 2009, Choudhury *et al.* 2022). Despite being said to have originated in the Indo-Chinese region, it has spread around the world and is especially grown on the northern plains of India during the winter, where it is productive. Well-drained soil that is high in organic matter and has a pH of 6.5 to 7 are ideal for growing spinach, which can produce yields of up to 10–20 t/ha. A variety of protective cultivation techniques have been developed with advances in agriculture, and they target specific agro climatic zones to help plants germinate more quickly. Protective cultivation involves the use of cropping techniques where the microclimate surrounding the plant is either partially or fully controlled to meet the specific needs of the plant species during their growth period.

The protected structure is engineered and built to efficiently harness solar insolation, optimizing the microclimate for plant growth (Choab *et al.* 2019). Net-house and polyhouse buildings are quite helpful for growing vegetables all year round in the Ladakh region. The net house system shields plants from external environments, promoting crop growth and enhancing both production and quality (Santosh *et al.* 2017a). With the introduction of modern techniques and tools through scientific intervention, production can be significantly increased per unit of land and water resources (Santosh *et al.* 2017b, Pahuja *et al.* 2013). The notion of a greenhouse is subject to individual interpretation. In the past, a greenhouse was made of glass and had a heating or cooling system that was used mostly in the winter but also other seasons. These days, polythene, glass, or—more frequently—polycarbonate sheets—all of which are clear, long-lasting (up to 12 years) and durable—are frequently seen in greenhouses.

Polyhouses are buildings with simple plastic sheets covering them. The transparency of the cladding material determines how much sunlight is absorbed by the vegetables and other items in the greenhouse. The greenhouse effect, which allows for the production of vegetables in colder locations, is the result of solar energy being trapped and increasing the interior temperature. In general, greenhouses enable photosynthetically active solar radiation with wavelengths between 400 and 700 nm to pass through while reflecting 43% of the net solar radiation. Climate change is a pressing global issue in the 21st century (Biswas *et al*. 2023). As a consequence, the greenhouse effect, ventilation and cooling systems are essential to understand during summer months to maintain interior temperatures below 35°C.

This study examined the impacts of three different growing media in open field, polyhouse, and net house habitats under varying climatic conditions: 100% cocopeat, garden soil, and a mixture of garden soil and cocopeat (50%–50%). Pots A, B, and C, which contain 100% garden soil, 100% cocopeat, and a combination of garden soil and cocopeat, respectively, illustrate each condition. Nine pots with roughly ten plants each are used in this configuration, which is repeated for every climate, for a total of ninety plants. Every pot is exposed to the same treatment procedures, which include routine temperature, humidity, and solar intensity monitoring. Characteristics of growth and yield are then assessed over time.

MATERIALS AND METHODS

Study area

The study site is located in The Neotia University campus in South 24 Parganas, West Bengal, India. It covers an area of about 8165.05 sq km and is between latitudes 21°29'0" north and 22°33'45" north and longitudes 88°3'45" east and 89°4'50" east. Temperatures in the area range from 36.3 degrees Celsius at maximums to 13.6 degrees Celsius at minimums, with an annual rainfall of 1750 to 1770 millimeters. With 380000 hectares of agricultural land, the population is estimated to be 81.6 lakhs. The most common soil types are loamy soil, which covers 194330 hectares, clay-loamy soil, which covers 101050 hectares, and clay soil, which covers 93280 hectares.

The methods we used in this study to draw conclusions were primarily based on accepted practices for cultivation and the gathering of meteorological data before tallying the results. The goal of the entire process is to determine which kind of medium will best promote spinach plant growth.

Methodology

Stepwise methodology for this research has been detailed below:

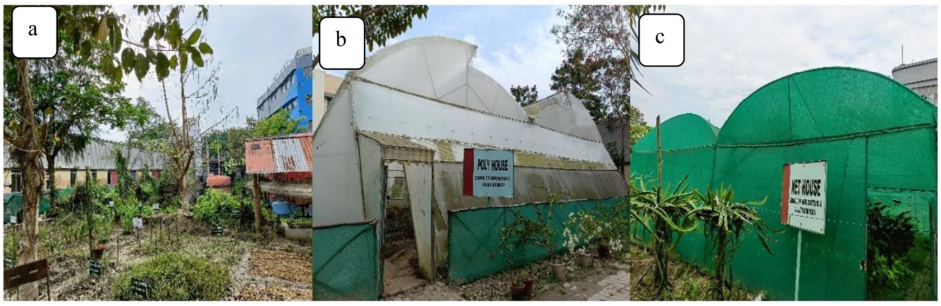

Fig. 1. Experimental area a) Open field, b) Polyhouse, c) Net house.

Step I

Site selection

The main goal of this research is to determine how environmental changes affect plant growth in various protective structure types and mediums. The first step is to choose appropriate places to conduct experiments. Open field, polyhouse, and net house are the three different environments that are selected (Figs. 1a-ac). A sunny spot close to water sources is chosen for the open field condition. Then, plants produced in various media are put in these three environments, and the results are evaluated by observations.

Step II

Media Preparation

After the place has been chosen, the right growing media must be chosen. Based on availability, affordability, and fit for the plants, three different types of medium are selected. Three different media consist of garden soil, 100% cocopeat, and a blend of 50% cocopeat and 50% garden soil (Figs. 2a-2c). Earthen pots are filled with the media, leaving a uniform

Fig. 2. Growing media preparation, a) Coco peat, b) Garden soil, c) Coco peat + Garden soil.

Fig. 3. Spinach seed sowing for different media a) Spinach Seed, b) Different media pot, c) Clay pot after sowing sed.

Fig. 4. Measurement of air temperature, humidity, and light intensity a) Thermo-hygrometer, b) Lux meter, c) Infrared thermometer.

space at the top. Within each type of media, other agronomic concepts including drainage, media depth, and moisture conditions are modified appropriately.

Step III
Seed sowing

The local seed market is where semi-savoy type spinach seeds are obtained, with the same selection criteria of cost and availability being applied (Figs 3a-3c). From the seed lot, fifty seeds that are of a suitable size are selected and given a 24-hr soak in water. The seeds are sufficiently hydrated the following day, at which point they are transferred to the main pot using a moist towel (Fig. 3a). Although the dibbling method is used here to guarantee equal plant spacing, disseminating is the usual approach for seeding green crops (Fig. 2b). Along the pot's circle, five holes with

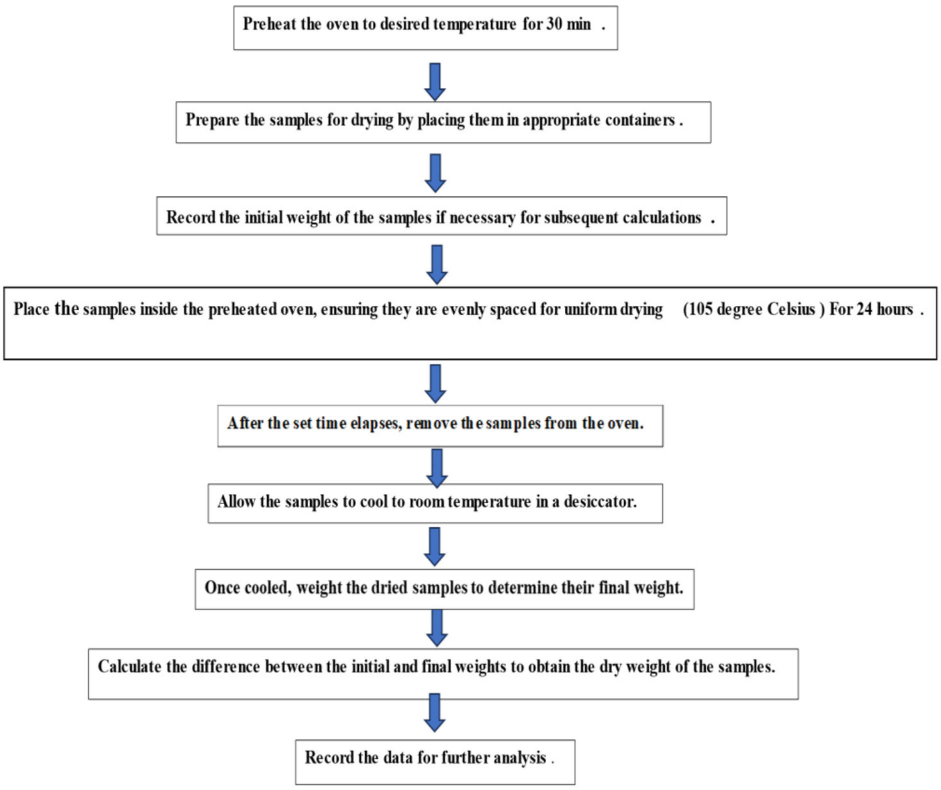

Fig. 5. Flowchart for estimation of dry weight (yield) of spinach.

1-2 cm depths are drilled, almost equally spaced apart. The next step is to cover two seeds per hole with the slightly moistened media to promote plant emergence. After sowing the spinach seeds, no water is given right away (Fig. 3c).

Step IV

Data collection of climate

Periodically gathered data on air temperature, humidity, soil temperature, and light intensity are just a few of the environmental characteristics that must be measured in order to evaluate and document the variability of climate conditions. In addition to a thermos-hygrometer, lux meters, and infrared thermometers are used to assess air temperature, humidity, sunlight intensity and soil surface temperature (Figs. 4a-4c). Furthermore, a straightforward meter scale is used to determine the plant height in each pot and other plant economic characteristics including leaf quantity, plant height, and plant count.

Step V
Crop performance

To estimate yield, we compute the dry weight of uprooted spinach using oven drying method (Fig. 4). After the plants are collected, the roots are removed, and the edible shoot portion is dried for 24 hrs at 105^{o} Celsius in an oven (Fig. 5). Then, weights are recorded from three pots in three distinct climate scenarios. We additionally calculated the plants' height, germination rate, and leaf count. We also estimated dry and wet weights of harvested spinach.

Step VI

Data analysis

This last step attempts to evaluate and support the ultimate purpose of the study. Data on plant growth are analyzed and averaged. The most appropriate media type and rotating structure types for a given set of climatic conditions are then determined by comparing the data.

RESULTS AND DISCUSSION

Microclimate

The temperature surrounding a plant is known as its microclimate. To increase greenhouse production economically and improve related structures, this should be changed. Every group of plants in this study was given one of the three types of varying climate conditions. Third is open field; first group is placed in polyhouse; second group is placed in net house.
They'd experienced diverse weather as a consequence. They therefore have distinct development and other characteristics. Data about significant environmental phenomena have been gathered and are analyzed three times a day, at 9 am, 1 pm. and 4 pm, we recorded the readings.

Air Temperature

Temperature controls transpiration and water status through stomatal regulation during photosynthesis, which has a substantial effect on the physiological development phases of plants, including flowering, germination, and total growth. Temperature fluctuations, including those between day and night, affect crops in diverse ways. The design of agricultural areas' structures and control systems is heavily influenced by climate temperature. In various protected crop structures (pcs), varied temperatures were recorded. The temperatures that were reported were affected by the covering materials that were used for these constructions. In contrast to the shade net structures, the average monthly maximum and minimum air temperatures in open fields were higher. Because of radiation, air temperatures have a tendency to be lower under shade nets. Furthermore, shade nets lessen wind speed and runoff, both of which can impact temperature (Stamps 2009). In addition, a sheltered structure promotes faster crop growth than an open field. If poly-film sheets are used in polyhouses, they can raise internal building temperatures by absorbing solar radiation, while shade nets lower internal building temperatures by reducing the quantity of solar radiation that enters the building (Pérez *et al.* 2006 and Santosh *et al.* 2017b). Variations in temperature in modified greenhouses and polyhouses illustrated how polyethylene affects temperature control. For the current study air temperature was measured at 15 days interval in three times daily (9 am, 1 pm, and 4 pm) at 2 m height from soil surface. Air temperature was found higher in poly house and medium in net house structure (Table 1).

Table 1. Monthly average air temperature in degree Celsius (Days after sowing (das)).

Days	Open field			Polyhouse			Net house		
	9 am	1 pm	4 pm	9 am	1 pm	4 pm	9 am	1 pm	4 pm
15 das	27.75	32.3	30.2	32.05	41.10	35.10	29.62	37.10	32.61
30 das	28.1	32.6	31.0	32.50	40.71	36.31	30.81	37.92	33.91
45 das	29.4	30.8	31.2	34.50	40.12	36.91	31.63	36.54	33.80
Average		30.37			36.59			33.77	

Relative humidity

The water vapor concentration of the air is indicated by relative humidity (RH), which is important for proper transpiration and illness prevention. The ideal RH range for plant growth is between 60 and 70%. Comparing polyhouses, modified greenhouses, and shade net houses to open fields revealed an increase in relative humidity. The RH was seen in open fields, polyhouses, and shade net houses. Compared to previous pieces, modified greenhouses that have both polyethene screen and shade net lessen the transmission of solar radiation. For the current study relative humidity was measured on 15 days interval (Days after sowing) in three times daily (9 am 1 pm, 4 pm) at 2 m height from soil surface. From the relative humidity study, it has been found that relative humidity is higher in poly house and medium in net house structure (Table 2).

Light intensity

Plant growth is governed by three light processes: Photosynthesis, photomorphogenesis, and photoperiodism. Variations in light directly impact the growth of the plant. Light facilitates photosynthesis by converting carbon dioxide into organic material and releasing oxygen in its presence. Net house crops experiences average light intensities 33.95 Klux, polyhouse experiences average light intensity 17.84 Klux and in open field experiences light intensity of 49.27 Klux. For the current study light intensity was measured on 15 days three times daily (9 am 1 pm, 4 pm) at 2 m height from soil surface. From the light intensity study, it has been found that light intensity is lower in poly house and medium in net house structure (Table 3). The result findings are consistent with those past study (Yasoda *et al*. 2018 and Satasiya *et al.* 2022).

Soil temperature

For each treatment the soil temperature was measured by using an infrared digital thermometer. The soil temperature was measured on 15 das (9 am, 1 pm, 4

Table 2. Monthly average relative humidity in percentage.

Days	Open field			Polyhouse			Net house		
	9 am	1 pm	4 pm	9 am	1 pm	4 pm	9 am	1 pm	4 pm
15 das	44%	62%	58%	50%	72%	62%	47%	67.2%	60.4%
30 das	48%	58%	52%	54.5%	68.5%	56.5%	52.2%	64.3%	54.8%
45 das	42%	57%	47%	49.2%	63.7%	51.2%	46.8%	63.1%	50.8%
Average	52%			59%			56%		

Table 3. Monthly average light intensity in Klux.

Days	Open field			Polyhouse			Net house		
	9 am	1 pm	4 pm	9 am	1pm	4 pm	9 am	1 pm	4 pm
15 das	41.30	53.90	32.50	16.98	18.19	16.86	31.96	38.09	31.44
30 das	35.70	66.90	40.50	16.65	18.14	19.87	30.57	38.53	32.08
45 das	45.30	76.00	51.30	17.52	18.48	17.89	31.56	39.09	32.26
Average	49.27			17.84			33.95		

Table 4. Monthly average soil temperature in degree Celsius.

				Garden soil					
Days		Open field			Polyhouse			Net house	
	9 am	1 pm	4 pm	9 am	1 pm	4 pm	9 am	1pm	4 pm
15 das	31.8	34.20	33.00	35.68	40.87	39.95	34.52	38.71	35.18
30 das	32.22	35.61	33.41	36.34	39.59	35.91	34.85	37.86	36.83
45 das	34.20	37.71	34.84	38.86	40.81	36.84	36.74	37.02	34.67
Average		34.11			38.32			36.26	
				Coco peat					
Days		Open field			Polyhouse			Net house	
15 das	33.6	37.01	35.7	37.60	42.62	40.21	33.94	36.30	35.50
30 das	32.04	35.80	36.51	34.61	37.38	36.27	36.75	39.87	37.7
45 das	34.17	38.51	36.02	35.94	40.37	37.80	36.30	39.70	35.45
Average		35.48			38.08			36.83	
				Coco peat + garden soil (50-50%)					
Days		Open field			Polyhouse			Net house	
15 das	30.5	35.47	34.87	35.90	41.71	38.54	33.5	36.80	34.63
30 das	32.2	35.64	33.68	34.14	37.54	36.59	36.51	39.92	32.61
45 das	33.67	37.2	34.81	36.37	39.90	35.70	35.57	38.45	31.42
Average		34.22			37.38			35.49	

pm) at soil surface. The soil temperature of polyhouses, net house consistently maintains a higher range of 20-30°C compared to open field conditions (Table 4). For garden soil open field condition has experienced lower temperature (34.11^{0}C) and in polyhouse structure has shown higher temperature (38.32^{0}C) and in net house experiences 36.26^{0}C temperature. For co-co-peat media also lower temperature (35.48^{0}C) and in polyhouse structure has shown higher temperature (38.08^{0}C) and in net house experiences 36.83^{0}C temperature. For Coco peat + garden soil (50-50%) media also lower temperature (34.22^{0}C) and in polyhouse structure has shown higher temperature (37.38^{0}C) and in net house experiences 35.49^{0}C temperature (Table 4).

Measurement of crop performance

Upon analyzing our data, it is evident that under open field conditions, better germination and yield are observed compared to those in protected cultivation structures (Table 5).

Crop yield

We conducted an experiment with two plants per pot to assess the wet weight and dry weight of spinach plants grown in various growing media. The aim was to determine which media performed best for germination and yielded higher production, aiding farmers in selecting optimal media for field culti-

Table 5. Shows average crop performance.

Types of media	Open field			Polyhouse			Net house		
	Germination rate/No. of plants	Number of leaf's	Plants height	Germination rate/No. of plants	Number of leaf's	Plants height (cm)	Germination rate/No. of plants	Number of leaf's	Plants height (cm)
Garden soil	6	6	20	8	6	19.2	7	6	22
Cocopeat	10	6	23	7	4	21.5	8	5	21
Cocopeat + garden soil (50-50%)	6	7	16.3	8	7	22	10	6	19.35

vation. Additionally, we analyzed different climatic conditions to ascertain under which conditions the plants thrived best. The procedure for estimating the wet weight and dry weight of the plants is outlined in the accompanying flow chart. Spinach yield was estimated immediately after harvesting from experimental plot. We also observed the highest average yield (wet weight) from cocopeat + garden soil media in open field conditions, while the lowest average yield was recorded from garden soil media in a net house structure. Additionally, we found that the average biomass/dry yield of spinach was highest when grown in cocopeat + garden soil media in open field conditions, with the lowest yield observed in garden soil media under net house field conditions.

CONCLUSION

Protected cultivation structures offer a great solar energy saver and increased temperature inside structures. Due to increased temperature in protected cultivation structures, reference crop evapotranspiration also vary according to temperature and radiation. In order to grow crops under partially or completely controlled environmental conditions for the best growth and productivity, greenhouses are framed or inflated structures covered in transparent or translucent material. They can be any size. Depending on the cropping system and level of environmental control, greenhouse crops can yield several times more than those grown outdoors. Form the sir temperature study is has found that air temperature is higher in poly house and medium in net house structure. Form the relative humidity study it has found that relative humidity is higher in poly house and medium in net house structure. Form the light intensity study it has found that light intensity is lower in poly house and medium in net house structure. For garden soil open field condition has experienced lower temperature (34.11^0C) and in polyhouse structure has shown higher temperature (38.32^0C) and in net house experiences 36.26^0C temperature. For coco-peat media also lower temperature (35.48^0C) and in polyhouse structure has shown higher temperature (38.08^0C) and in net house experiences 36.83^0C temperature. For Coco peat + garden soil (50-50%) media also lower temperature (34.22^0C) and in polyhouse structure has shown higher temperature (37.38^0C) and in net house experiences 35.49^0C temperature. We observed the highest average yield (wet weight) from cocopeat + garden soil media in open field conditions, while the lowest average yield was recorded from garden soil media in a net house structure. Additionally, we found that the average biomass/dry yield of spinach was highest when grown in cocopeat + garden soil media in open field conditions, with the lowest yield observed in garden soil media under net house field conditions. Thus, we conclude that spinach plants thrive well in coco peat under open field conditions.

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REFERENCES

Biswas A, Duary S, Islam A, Bhattacharjee S (2023) Water footprint and productivity of lettuce with non-conventional water resources. *Biological Forum – An International Journal* 15(4): 01-04.

Choab N, Allouhi A, El Maakoul A, Kousksou T, Saadeddine S, Jamil A (2019) Review on greenhouse microclimate and application: Design parameters, thermal modeling and stimulation, climate controlling technologies. *Solar Energy* 191:109-137.

Choudhury S, Islam N, Mustaki S, Uddain J, Azad MOK, Choi KY, Naznin MT (2022) Evaluation of the different lowtuch protective cultivation approaches to improve yield and phytochemical accumulation of papaya (*Carica papaya* L.) in Bangladesh. *Horticulturae* 8(3): 210. DOI: https://doi.org/10.3390/horticulturae8030210

Max JFJ, Horst WJ, Mutwiwa UN, Tantau HJ (2009) Effects of greenhouse cooling method on growth, fruit yield and quality of tomato (*Solanum lycopersicum* L.) in a tropical climate. *Scientific Hort* 122(2): 179-186.

Pahuja R, Verma HK, Uddin M (2013) A wireless sensor network for greenhouse climate control." *IEEE Pervasive Computing* 12(2): 49-58.

Pérez M, Plaza BM, Jiménez S, Lao MT, Barbero J, Bosch JL (2006) The radiation spectrum through ornamental net houses and its impact on the climate generated. *Acta Horticulturae* 719: 631–636. DOI: https://doi.org/10.17660/ActaHortic.2006.719.73

Santosh DT, Tiwari KN, Kumar Vikas, Singh Raja, Gopala Reddy A (2017a) Microclimate control in greenhouse. *International Journal of Current Microbiology and Applied Sciences* 6(3): 1730-1742.

Santosh DT, Tiwari KN, Singh VK (2017b) Influence of different protected cultivation structures on water requirements of winter vegetables. *International Journal of Agriculture, Environment and Biotechnology* 10(1): 93-103. DOI: 10.5958/2230-732X.2017.00004.3

Satasiya RM, Sojitra MA, Kothiya AV, Chuhan PM (2022) Effect of protected environment on off-season seedling raising of papaya. *Environment and Ecology* 40(2B): 650-655.

Stamps RH (2009) Use of colored shade netting in horticulture. *Hort Science* 44(2): 239-241. DOI: https://doi.org/10.21273/HORTSCI.44.2.239

Yasoda PGC, Pradheeban L, Nishanthan K, Sivachandiran S (2018) Effect of different shade levels on growth and yield performances of cauliflower. *International Journal of Environment, Agriculture and Biotechnology* 3(3): 948-953. DOI: http://dx.doi.org/10.22161/ijeab/3.3.30