**A comprehensive review on protected cultivation of horticultural crops: Advances and Sustainability**

**Abstract**

Horticultural crop growing under protection has become a vital method in contemporary agriculture, providing several advantages like improved quality, higher yield, and defence against pests and unfavourable weather. The purpose of this thorough research is to outline the present state of protected cultivation methods and investigate their potential in horticulture going forward. The examination starts out by going over the many kinds of protected cultivation structures as well as their benefits and drawbacks, such as shade houses, high tunnels, and greenhouses. It then emphasizes how important protected farming is in tackling the issues of global food security by guaranteeing crop output all year round and lowering reliance on seasonal fluctuations. The review goes on to examine how protected cultivation methods, such as enhanced crop morphogenesis, better precipitation control, and the optimization of environmental parameters like temperature, humidity, and carbon dioxide levels, affect the growth and development of horticultural crops. Additionally, the use of cutting-edge technologies such as vertical farming, hydroponics, and aeroponics in protected growing systems is investigated, with a focus on how they might maximize crop output while consuming the fewest resources possible. The study also explores the difficulties and limitations associated with putting protected cultivation into practice, such as financial concerns, energy needs, and the need for artificial inputs. It talks about eco-friendly and sustainable ways to lessen these problems and support ecological balance, like using renewable energy sources and switching to organic farming methods. The paper concludes by outlining some potential future developments and trends in protected cultivation, such as the application of artificial intelligence, precision agriculture methods, and smart farming technology. In the end, these developments could result in higher yield and quality improvements in the production of horticulture crops by further optimizing resource use, enhancing automation, and improving crop monitoring and management.

**Keywords:** Food security, Eco-friendly, Hydroponics, Greenhouses, Protected Cultivation

**Introduction**

“The term protected cultivation refers to the practice of growing crops in an enclosed or partially enclosed environment, such as greenhouses, shade houses, or high tunnels” [1,20,21]. “The main goal of protected cultivation is to optimize environmental factors while creating a controlled microclimate that protects the crops from pests, diseases, and unfavourable weather conditions” [2]. “It involves the use of structures, materials, and technologies that provide a protective barrier and allow for the manipulation of temperature, humidity, light, and other environmental variables” [3, 22]. This technique allows for year-round or out-of-season cultivation, prolongs the growing season, improves crop quality and yield, and lessens reliance on external factors. Protected cultivation is widely used in the production of a variety of horticultural crops, including fruits, vegetables, flowers, and herbs [4, 23]. “Crop yield and quality are greatly impacted by biotic and abiotic stressors in the current shifting environment” [5]. “Extreme temperatures, sunlight, water availability, relative humidity, weeds, nutrient deficits, wind speed, carbon dioxide concentration, and the prevalence of illnesses and insect pests are some of the issues that North Indian horticulture crop production encounters” [6, 24]. “Protected growing methods have shown themselves to be an effective way to overcome these limitations, particularly in harsh climates” [7, 25]. “Using facilities like greenhouses, protected farming entails producing higher-quality crops outside of their typical growing seasons” [8, 26, 27]. This method guarantees the delivery of fresh product, especially in peri urban areas, while also increasing farmer income and cutting down on transportation time [9, 28, 29].

“Greenhouses are structures that are coated with transparent materials that filter radiation selectively, such glass or polythene. They trap long-wavelength solar light within while permitting short-wavelength radiation to flow through” [10, 32]. As a result, solar energy is trapped, increasing the structure's interior temperature and producing a greenhouse effect [11, 30, 31]. “The high temperature has an impact on the photosynthetic rate, stomatal aperture, transpiration, and leaf temperature of plants” [12, 33]. The physiological state of the plants can be manipulated by regulating the greenhouse environment [13]. “As an example, when the greenhouse is closed at night, plant respiration causes the CO2 levels to rise. The following day's early morning hours saw the use of this increased CO2 for photosynthesis. Fast growth and higher yield are encouraged by the greenhouse's higher temperature, relative humidity, CO2, and better nutrition” [14, 34, 35]. “Cooling devices like ventilation, fogging, or fan pad systems can be used to control the temperature inside a greenhouse” [15, 36]. These methods optimize the output potential of chosen vegetable crops and allow for year-round production. In protected farming, yields are further increased by closer planting and higher plant density [16, 37, 38].

“Open-field agriculture and sheltered cultivation use different management techniques. Multi-story greenhouse crop growing has become essential in peri-urban locations to satisfy the need for fruit tree nurseries, fresh vegetables, strawberries, and flowers” [17, 39, 40]. Protected cultivation systems use a variety of methods, including fertigation, drip irrigation, mulching, and naturally ventilated polyhouses [18, 43]. “Furthermore, walk-in polytunnels have lately become a lucrative technology in India's northern plains, demonstrating their potential for off-season nurseries and the cultivation of crops including tomatoes, capsicum, and cucurbits” [19, 42].

**The importance of the protected cultivation and its compass**

* Long-term advanced manufacturing quality and quantity
* Water usage is maximized and consumption is decreased by 40–50%.
* Use of inputs efficiently
* The frequency of illness and pests is decreased or eliminated
* Throughout the period, crops will be fully grown.
* Fashionable technology for the synthetic goods made from valuable crops, such as flowers, pharmacies, etc.
* Additional tone: job opportunities for educated young people on grants
* The hothouse's microclimate and bug-evidence point were manipulated for factory parentage, which led to the development of new seed varieties and products.

**Need of protected cultivation**

Shops are protected from biotic variables like pests and the frequency of complaints, as well as abiotic stressors like temperature, water shortages or excesses, and hot and cold waves [41, 53]. “Reduced use of water and controlled growth of weeds Increasing output per unit area. Reducing the amount of fungicides used in agricultural products. Encouragement of high-quality, high-value horticulture production. Propagation, a valuable adaptation, and the addition of crops that are proven to thrive in particular areas Off-season and year-round products of fruit, vegetable, or flower crops. The result of genetically superior and complaint-free transplants. New developments in protected ornamental crop cultivation adaptation of agricultural techniques for flower production in indoor greenhouses. Recently, growing vegetables in greenhouses has become more popular in India as a way to produce high-quality products for export in the off-season” [52]. “A floriculture unit can only succeed if it produces ornaments with an export-focused approach and does it efficiently. is excellent, and the quality is outstanding. Using the newest technologies in greenhouse production is necessary to maintain affordable prices while guaranteeing consistency in production quantity and quality. For instance, studies on the standardization of agricultural technologies. Useful Applications of Low-Cost Greenhouses The cultivation of roses, gerberas, carnations, and tuberoses Invariably superior to the flowers and more fruitful” [11, 50, 51]. Emerging patterns of protected vegetable crop production People have been eating vegetables for decades because they are a good source of nourishment.

“Many growers in peri-urban areas of the country will be able to successfully diversify their traditional husbandry by embracing or utilizing colourful situations of defended civilization technologies for the production of horticultural crops looking to their coffers, the vacuity of arising requests of usual and unusual off-season horticultural yield, the year-round demand of high-value vegetables like slicing tomatoes, coloured peppers, parthenocarpy cucumbers, etc” [54, 55]. Another area where the traditional nursery caregiving system needs to be completely diversified is in the high-quality nursery growing of vegetables. Because they don't have much money, low-cost or medium-sized farmers use modest structures [56]. In contrast to open field conditions, polyhouse civilization of vegetables is emerging as a technical product technique to break the seasonal barrier and overcome biotic and abiotic constraints, resulting in an extended crop duration. When compared to open field settings, the highest number of fruit weights and yield were obtained in poly homes. While it was the smallest in open field conditions, several protected technologies showed lower net return and BC in the poly house.

**Emerging patterns in seed production using protected cultivation**

“Nowadays, efficient growth depends on the growing of seeds, and seeds grown in polyhouse structures are immune to the diseases and pests that are prevalent in open agriculture. Several structures are used in order to produce seeds: Insect-proof net dwellings, walk-in tunnels, low-cost poly-houses, climate-controlled greenhouses, semi-controlled greenhouses, naturally ventilated greenhouses, and plastic low tunnels are some of the main constructions” [57, 58].

**1. Climate and semi-climate-controlled glasshouses:** “Poly houses are used to produce high-value exotic crops for challenging growing seasons and higher yields. Glasshouses with temperature regulation or semi-climate control are also used. Otherwise, the growth season is shorter on an open field. High-value foods can be grown in these structures, including parthenocarpy cucumbers, sweet peppers, cherries, and sliced tomato products” [59, 60]. In comparison to seeds grown under other structures or in open fields, the primary barrier to the usage of this type of structure is the initial or starting point of construction and ongoing cost of similar glasshouses, which significantly raises the cost of seed. However, seeds with comparable structures consistently produce and are of higher quality.

**2. Naturally ventilated greenhouses:** These can be used to grow tomatoes, sweet peppers, cucumbers (including parthenocarpy cucumbers), summer squash, muskmelon, and other vegetables as seeds since they naturally aerate the air [50]. However, the time required for cultivation and seed production is shorter than in greenhouses with climate control or semi-climate control.

**3.** Sweet pepper, tomato, brinjal, and other vegetable seeds, including cucurbits, can be economically produced in insect-proof net buildings. These structures can shield crops from fruit bores and other insects, including viruses, during and after rainy seasons. The seed output is consistently lower than in all other types of greenhouses, but the production costs are also significantly lower.

**4.** Cucurbit seeds, such as those for muskmelon, watermelon, summer squash, bottle gourd, bitter gourd, etc., can be produced in walk-in tunnels [25, 49]. By warming the soil for crop development, high tunnels are utilized in temperate regions of the world to prolong the growing season [24, 48].

**Intercultural activities in protected agriculture**

* **Pruning and training**

In solanaceous and cucurbit vegetables, the source-sink relationship affects the growth pattern, fruit-bearing pattern, and seed yield. Tomatoes can have determinate, semi-determinate, or indeterminate growth habits [61, 62]. Indeterminate varieties/hybrids are preferred in greenhouse hybrid seed production. These plants can be grown for a long time and produce several fruit trusses. Indeterminate tomato cultivars that have been streaked and upright-trained. Side branches need to be clipped to leave only one stem or, at most, two stems. Less frequent and not preferred for greenhouse seed production are deciduous or semi-deciduous varieties [63, 64]. The first to fourth clusters at each branch are often selected for emasculation in the case of hybrid seed production. In single stems, terminal pinching is carried out six weeks later. Regular lateral shoot removal is done. Only when the fourth cluster forms do the leaves start to defoliate [65, 77, 78]. In greenhouse tomato crops, training and pruning are regular procedures, thus it is always advantageous to pay special attention for a high seed output. Only the shoots that develop on the stem beneath the first branching or a few of the weaker side shoots are usually pruned in sweet peppers. To produce enough dry matter, a vast area of active leaves is needed because pepper leaves have a low photosynthetic efficiency [66, 67]. Only a small percentage of situations where the growth is abundant are pruned. Under protected culture, pepper stem structure is often too weak.

* **Improvements to irrigation infrastructure and microirrigation**

A major contributor to green yields in arid and semi-arid regions is the water system. To ensure optimal growth, desired output, and acceptable organic product quality, plants must have a reliable source of water and nutrients. One of the best methods for applying water and fertilizer to agricultural harvests is the drip water system, which is being promoted to increase water efficiency and supplement use productivity in the face of concerns about natural corruption and water accessibility. It is a water system technique in which water is applied as beads at specific locations (the root spread region) and assisted through a line framework to the mark of utilization, leaving some of the area between the yields dry [44, 45, 46, 47]. It has been proposed to use a Dribble water system to receive widely distributed harvests, such as vegetables, cotton, sugarcane, and plantations. Water shortages are occurring in many areas due to limited availability. It is anticipated that growing food demand will continue to contribute to the increasing demand on water resources. Enhancing the efficiency of current water resources, such as collecting more food from limited water resources, is the greatest long-term strategy for managing water scarcity, according to water executives' experts. As a result, adopting water-saving technologies is essential for efficient agricultural water use. When compared to surface and sprinkler water system strategies, water conservation in the trickling water system strategy is mostly related to the controlled use of water in limited areas of the entire field [68]. Only a portion of the all-out field's soil surface and root zone gets wetted as a result of the way water is applied by a trickle water system framework. Furthermore, limited soil wetting indicates a smaller area that may be utilized by plants that were created with dribbling water systems, necessitating frequent water and supplement treatments. There are basically two ways to implement a water shortage system for a yield:

* By applying less water to the system,
* By extending the time between water system cycles.

With a trickling water system, completing the two steps is not difficult.

**Interface between fertilizer and water**

**Fertigation:** In order to meet the wholesome requirements at different stages of harvest development, fertilization is the slow and regulated use of necessary composts or plant supplements (water solvent) with the water system water. The full amount of manure that a particular tree requires is typically spread in several sections. Depending on the wholesome need at different stages of harvest, the necessary number of composts can be administered in ten, fifteen, or more parts under fertilization. Fertigation is a technique that allows plants to get small amounts of compost before the crop's vegetative season. The measurement increases as the burden of natural products and supplement requirements increases, and then decreases as plants near the end of the crop's cycle [69]. Instead of only a few massive pieces, this establishes the necessary manure measures throughout the development cycle. When compared to conventional methods, fertilization produces yields that are on par with or higher while leaving substantial reserve funds in the compost. The secret to excellent yield and produce quality is the proper ratio of water to supplements [70]. Protected Growth of Green Yields Both of the following three methods can be utilized to incorporate composts (fluid or water-solvent) into the dribbling framework:

**1. Manure tank:** a portion of the water that flows into the structure passes through a manure tank before rejoining the main stream.

**2. Venturi:** A venturi is installed in a shunt pipe parallel to the main line, providing enough pull to allow the compost to be arranged within the framework.

**3. Fertigation syphon:** Compost arrangement is introduced into the mainline using a positive dislodging syphon.

The main guidelines for determining the amount, kind, and time of manure application are the following: the plants' request for supplements both at all stages of development and at different points in time; the soil's fruitfulness; the physical-synthetic characteristics of the soil; the compost's qualities, including its structure, dissolvability, accommodation, and cost of the available manure material; and the water system's water quality [71, 72]. Knowledge of the nutritional requirements for different yields is crucial for successful fertigation. It is important to understand that the water system approach may not affect the organic product trees' absolute nutrient requirements. This has led to a far more realistic demand for computerization and sophisticated mechanics given the continued demands on human labor. Mechanization has lately emerged and entrenched itself in the context of many processes, such as harvesting [34, 73].

**Challenges in Protected Vegetable Farming in India**

In India, protected vegetable growing is very new, although being very old. Very little attention has been paid to utilizing the vast potential of protected vegetable agriculture.
Some restrictions and problems that restrict the production of protected vegetables in India are as follows:

1. No particular breeding work has been done to produce types or hybrids that are suitable for production in greenhouses or other protected environments, despite the significance of vegetables like the tomato, cherry tomato, sweet pepper, and cucumber. The high cost of exotic seeds prevents Indian farmers from purchasing them.

2. Despite being sold domestically, some of these vegetable varieties do not meet the standards for export or upscale markets.

3. Climate-controlled greenhouses are unsuitable for Indian producers because to their high initial cost and continuous operational expenses.

4. The heating and cooling systems of the greenhouses require a more consistent power source in many parts of the nation.

5. Sunlight exposure during very important periods may lower the yields of certain plants in some areas, such as sweet pepper in winter circumstances in Delhi [74].

6. Despite the country's several agro-climatic regions, not much has been done to standardize greenhouse and other protected structure designs.

7. Various types of covered structures have not been used to test potential vegetable crop production technologies for the nation's diverse agroclimatic zones.

8. It is difficult to obtain the materials for cladding that are required. Furthermore, greenhouses are not equipped with the right tools to regulate the atmosphere.

9. No specific research projects are in place to cultivate protected crops.

10. There is a lack of packaging and on-farm value-added materials to supply markets with high-quality products [30].

**Conclusion**

The practice of producing crops in a controlled setting, known as protected farming, enables the management of variables including temperature, light, humidity, and other factors according to the crop's particular needs. This regulated setting raises the total yield and encourages healthier plants. Protected farming methods come in many forms, such as plastic tunnels, insect-proof net houses, shade net houses, naturally ventilated polyhouses, forcibly ventilated greenhouses, and mulching, raised beds, trellising, and drip irrigation [75]. By prolonging the cultivation time or facilitating the production of crops during off-seasons, these techniques can be used singly or in combination to produce a favourable growth environment that protects plants from harsh climates. By decreasing evaporation losses, drip irrigation combined with raised beds and mulch films improves soil moisture retention and helps manage weeds. Protected horticulture allows crops to grow in a controlled environment where variables like light, rainfall, and temperature may be changed according to the needs of the crop. Healthy plants are encouraged in this setting, and overall productivity rises [76]. Various structures and methods, including as high tunnels, net houses, drip irrigation, micro irrigation, variety selection, and precise technology, are all part of safe agricultural practices. The ideal growth environment is created by shielding crops from unfavourable weather, prolonging the growing season, and permitting off-season crop production. Adopting this advancement provides advantages including higher soil moisture retention and weed control.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**References**

1. Lamichhane P, Adhikari J, Poudel A. Protected cultivation of horticultural crops in Nepal: Current practices and future needs. Archives of Agriculture and Environmental Science. 2023;8(2):268- 273.
2. Ayushi Trivedi, S.K. Pyasi and Galkate, R.V. 2018. Estimation of Evapotranspiration using CROPWAT 8.0 Model for Shipra River Basin in Madhya Pradesh, India. Int.J.Curr.Microbiol.App.Sci. 7(05): 1248-1259.
3. Jewett T, Jarvis W. Management of the greenhouse microclimate in relation to disease control: A review. Agronomie. 2001;21(4):351-366.
4. Gruda N, Tanny J. Protected crops. Horticulture: Plants for People and Places, Production Horticulture. 2014;1:327-405.
5. TÃ¼zel Y, Kacira M. Recent developments in protected cultivation. In VIII SouthEastern Europe Symposium on Vegetables and Potatoes. 2021, September;1320:1- 14.
6. Rasheed R, Ashraf MA, Iqbal M, Hussain I, Akbar A, Farooq U, Shad MI. Major constraints for global rice production: Changing climate, abiotic and biotic stresses. Rice research for quality improvement: Genomics and genetic engineering: Breeding Techniques and abiotic Stress Tolerance. 2020;1:15-45.
7. Shil S. Weather parameters and it’s impact on agricultural production-A review. Innovative Farming. 2018;3(4):141-149.
8. D'antonio CARLA, Meyerson LA. Exotic plant species as problems and solutions in ecological restoration: A synthesis. Restoration Ecology. 2002;10(4):703-713.
9. Sabir N, Singh B. Protected cultivation of vegetables in global arena: A review. Indian Journal of Agricultural Sciences. 2013;83(2):123-135.
10. Van Veenhuizen R, Danso G. Profitability and sustainability of urban and periurban agriculture. Food & Agriculture Org. 2007; 19.
11. Rahman F, Abid K, Schmidt C, Pfaff G, Koenig F. Interference pigment coated solar cells for use in high radiant flux environments. JJMIE. 2010;4(1).
12. Gorjian S, Calise F, Kant K, Ahamed MS, Copertaro B, Najafi G, et al. A review on opportunities for implementation of solar energy technologies in agricultural greenhouses. Journal of Cleaner Production. 2021;285:124807.
13. Pallas Jr JE, Michel BE, Harris DG. Photosynthesis, transpiration, leaf temperature, and stomatal activity of cotton plants under varying water potentials. Plant Physiology. 1967;42(1):76-88.
14. Paradiso R, Proietti S. Light-quality manipulation to control plant growth and photomorphogenesis in greenhouse horticulture: The state of the art and the opportunities of modern LED systems. Journal of Plant Growth Regulation. 2022; 41(2):742-780.
15. De Gelder A, Dieleman JA, Bot GPA, Marcelis LFM. An overview of climate and crop yield in closed greenhouses. The Journal of Horticultural Science and Biotechnology. 2012;87(3):193-202.
16. Sethi VP, Sharma SK. Survey of cooling technologies for worldwide agricultural greenhouse applications. Solar Energy. 2007;81(12):1447-1459.
17. Nordey T, Basset-Mens C, De Bon H, Martin T, Déletré E, Simon S, et al. Protected cultivation of vegetable crops in sub-Saharan Africa: limits and prospects for smallholders. A review. Agronomy for Sustainable Development. 2017;37:1-20.
18. Pancharatnam P. Agriculture Letters. Agriculture Letters. 4.
19. Aditya P, Rao V, Mohapatro S, Chandra V, Nanda C, Suman S. Future trends in protected cultivation: A Review; 2023.
20. Singh AK, Sabir N. Role of protected cultivation as green technology for sustainable environment: Future, Prospect, Potential, Production, Protection, and Profit. In Handbook of Research on Green Technologies for Sustainable Management of Agricultural Resources. IGI Global. 2022;81-107.
21. Ayushi Trivedi, S.K. Pyasi and Galkate, R.V. 2018. A review on modelling of rainfall – runoff process. The Pharma Innovation Journal 7(4): 1161-1164.
22. Ayushi Trivedi, Avinash Kumar Gautam and Harshita Vyas. 2017. Comparative analysis of dripper. Agriculture Update TECHSEAR 12(4): 990-994.
23. Biswas BC, Kumar L. Fertilizer and Mineral Nutrition. 2010;41(6):3-14.
24. Gerson Uri, Phyllis G. Weintraub. Mites for the control of pests in protected cultivation. Pest Management Science: formerly Pesticide Science. 2007;63(7):658-676.
25. Jiang WJ, Qu D, Mu D, Wang L. Protected cultivation of horticultural crops in China. Hort. Rev. (Amer. Soc. Hort. Sci.). 2004;30:115-162.
26. Lamont William J. Overview of the use of high tunnels worldwide. HortTechnology. 2009;19(1):25-29.
27. Nair R, Barche S. Protected cultivation of vegetables presents status and prospects in India. Indian Journal of Applied Research. 2014;4(6):245-247.
28. Nimbrayan PK, et al. A review on the economic aspect of protected cultivation in India. Research trends in horticulture sciences; c2018. p. 43-59.
29. Pachiyappan Prakash, et al. Protected cultivation of horticultural crops as a livelihood opportunity in Western India: An economic 2022;14(12):7430.
30. Praneetha S, Muthuselvi R. Quality seed production of vegetable crops under protected structures.
31. Rathee, Mandeep, et al. Integrated pest management under protected cultivation: A review. Journal of Entomology and Zoology Studies. 2018;6(2):1201-1208.
32. Sabir Naved, Balraj Singh. Protected cultivation of vegetables in the global arena: A review. Indian Journal of Agricultural Sciences. 2013;83(2):123-135
33. Sindhu SS. Recent varietal development of flower crops in India. Progressive Horticulture. 2018;50(1-2):55-63.
34. Singh HP, Surender S Dhankhar, Dahiya KK. Horticultural crops. Stadium Press (India) Pvt Limited; c2009.
35. Ummyiah HM, et al. Protected cultivation of vegetable crops under temperate conditions. Journal of Pharmacognosy and Phytochemistry. 2017;6(5):16291634.
36. Van Henten, Eldert Jan, et al. Robotics in protected cultivation. IFAC Proceedings. 2013;46(18).
37. Wittwer SH, Castilla N. Protected cultivation of horticultural crops 1995;5(1):6-24. worldwide. HortTechnology.
38. Wittwer, Sylvan H, Nicolas Castilla. Protected cultivation of horticultural crops worldwide. HortTechnology. 1995;5(1):6-24.
39. Ayushi Trivedi and Avinash Kumar Gautam. 2017. Hydraulic characteristics of micro-tube dripper. LIFE SCIENCE BULLETIN 14 (2): 213-216.
40. Avinash Kumar Gautam, Atul Kumar Shrivastava and Ayushi Trivedi. 2017. Effect of raised bed, zero and conventional till system on performance of soybean crop in vertisol. Agriculture Update 12 (4): 923-927.
41. Ayushi Trivedi and Avinash Kumar Gautam. 2019. Temporal Effects on the Performance of Emitters. Bulletin of Environment, Pharmacology and Life Sciences 8 (2): 37-42.
42. Surbhi Suman, Ankita Sharma and Ayushi Trivedi. 2020. Bioactive Phytochemicals in Rice Bran: Processing and Functional Properties: A Review. Int.J.Curr.Microbiol.App.Sci Special Issue-11: 2954-2960.
43. Ayushi Trivedi, S. K. Pyasi, R.V. Galkate and Vinay Kumar Gautam. 2020. A Case Study of Rainfall Runoff Modelling for Shipra River Basin. nt.J.Curr.Microbiol.App.Sci Special Issue-11: 3027-3043.
44. Bhanu Pratap Singh, Pradeep Srivastava, Ayushi Trivedi, Deepesh Singh. 2021. Application of Geospatial Techniques for Hydrological Modelling. International Journal of Multidisciplinary Research and Analysis : 181-192.
45. Ayushi Trivedi and Manoj Kumar Awasthi. 2020. A Review on River Revival. International Journal of Environment and Climate Change 10(12) : 202-210.
46. Vinay Kumar Gautam, M. K. Awasthi and Ayushi Trivedi. 2020. Optimum Allocation of Water and Land Resource for Maximizing Farm Income of Jabalpur District, Madhya Pradesh. International Journal of Environment and Climate Change 10(12): 224-232.
47. Ayushi Trivedi, Bhanu Pratap Singh and Nirjharnee Nandeha. 2020. Flood Forecasting using the Avenue of Models. JISET - International Journal of Innovative Science, Engineering & Technology 7(12) : 299-311.
48. Malay Singh, Y. K. Tiwari, M. K. Awasthi and Ayushi Trivedi. 2020. Analysis of Geospatial Causes for Lowering Discharge in Kanari River. Int.J.Curr.Microbiol.App.Sci (2020) Special Issue-11: 2840-2853.
49. Ayushi Trivedi, S. K. Pyasi and R. V. Galkate. 2019. Impact of Climate Change Using Trend Analysis of Rainfall, RRL AWBM Toolkit, Synthetic and Arbitrary Scenarios. Current Journal of Applied Science and Technology 38(6): 1-18
50. Ayushi Trivedi. 2019. Reckoning of Impact of Climate Change using RRL AWBM Toolkit. Trends in Biosciences 12(20) : 1336-1337.
51. Ayushi Trivedi and Manoj Kumar Awasthi. 2021. Runoff Estimation by Integration of GIS and SCS-CN Method for Kanari River Watershed. Indian Journal of Ecology 48(6): 1635-1640.
52. Ayushi Trivedi, Vinay Kumar Gautam, S.K.Pyasi and Galkate R.V. 2020. Development of RRL AWBM model and investigation of its performance, efficiency and suitability in Shipra River Basin. Journal of Soil and Water Conservation 20(2) : 1-8.
53. Deepak Katkani, Anita Babbar, Vipin Kumar Mishra, Ayushi Trivedi, Shweta Tiwari and Rohit Kumar Kumawat. 2021. A Review on Applications and Utility of Remote Sensing and Geographic Information Systems in Agriculture and Natural Resource Management. International Journal of Environment and Climate Change 12 (4): 1-18.
54. Ayushi Trivedi, K.V.R. Rao, Yogesh Rajwade, Deepika Yadav and Neelendra Singh Verma. 2022. Remote Sensing and Geographic Information System Applications for Precision Farming and Natural Resource Management. Indian Journal of Ecology 49(5): 1624-1633.
55. Ayushi Trivedi and Vinay Kumar Gautam. 2022. Decadal analysis of water level fluctuation using GIS in Jabalpur district of Madhya Pradesh. Journal of Soil and Water Conservation 21(3) : 250-259.
56. Neelendra Singh Verma, KV Ramana Rao, Yogesh Rajwade, Deepika Yadav and Ayushi Trivedi. 2023. Growth and yield of strawberry (Fragaria x ananassa Duch) under different mulches in vertisols of Madhya Pradesh. The Pharma Innovation Journal 12(11): 1324-1327.
57. Nirjharnee Nandeha, Ayushi Trivedi, Neelendra Singh Verma, Neha Kushwaha and Satish Kumar Singh. 2023. Benefits and Challenges of Indian Organic Farming: A Comprehensive Review. International Journal of Environment and Climate Change 13(9): 2142-2151.
58. Deepika Yadav, Yogesh Rajwade, K.V. Ramana Rao, Ayushi Trivedi and Neelendra Singh Verma. 2023. Adoption of Plastic Mulching Techniques for Enhancing African Marigold ( L.) Production. Indian Journal of Ecology 50(3): 685-689.
59. Vinay Kumar Gautam , Ayushi Trivedi and M.K. Awasthi. 2023. Optimal water resources allocation and crop planning for Mandla district of Madhya Pradesh. Indian Journal of Soil Conservation 51(1): 68-75.
60. Ayushi Trivedi, M. K. Awasthi, Vinay Kumar Gautam, Chaitanya B. Pande and Norashidah Md Din. 2023. Evaluating the groundwater recharge requirement and restoration in the Kanari river, India, using SWAT model. Environment, Development and Sustainability. Doi: https://doi.org/10.1007/s10668-023-03235-8
61. Deepika Yadav, K V Ramana Rao, Ayushi Trivedi, Yogesh Rajwade and Neelendra Verma. 2023. Reflective mulch films a boon for enhancing crop production: A review. Environment Conservation Journal 24 (1):281-287.
62. Nirjharnee Nandeha, Ayushi Trivedi, M L Kewat, S.K Chavda, Debesh Singh, Deepak Chouhan, Ajay Singh, Akshay Kumar Kurdekar and Anand Dinesh Jejal. 2024. Optimizing bio-organic preparations and Sharbati wheat varieties for higher organic wheat productivity and profitability. AMA 55(1): 16739- 16760.
63. Ashwini Kumar, Ayushi Trivedi, Nirjharnee Nandeha, Girish Patidar, Rishika Choudhary and Debesh Singh. 2024. A Comprehensive Analysis of Technology in Aeroponics: Presenting the Adoption and Integration of Technology in Sustainable Agriculture Practices. International Journal of Environment and Climate Change 14(2): 872-882.
64. Smita Agrawal, Amit Kumar, Yash Gupta and Ayushi Trivedi. 2024. Potato Biofortification: A Systematic Literature Review on Biotechnological Innovations of Potato for Enhanced Nutrition. Horticulturae 2024, 10, 292. https://doi.org/10.3390/horticulturae10030292. 1-17.
65. Ashwini Kumar, Ayushi Trivedi, Nirjharnee Nandeha and Niveditha MP. 2024. Sustainable Agriculture Development and Optimim Utilization of Natural resources: Striking a Balance. Journal of Scientific Research and Reports. 30(5): 477-486.
66. Vikas Gupta, Ayushi Trived, Nirjharnee Nandeha, Duyu Monya, K. Dujeshwer, Amit Kumar Pandey and Ashutosh Singh. 2024. Micro Plastic Pollution in Soil Environment: A Comprehensive Review. Journal of Scientific Research and Reports. 30(6): 412-419.
67. Ashwini Kumar, Dibyajyoti Mahanta, Mohini M. Dange, Ayushi Trivedi, and Nirjharnee Nandeha. 2024. “Global Challenges Facing Plant Pathology: A Review on Multidisciplinary Approaches to Meet the Food Security”. Journal of Scientific Research and Reports 30 (6):884-92. https://doi.org/10.9734/jsrr/2024/v30i62106.
68. Prabha Haldkar, Mohini M. Dange, Ayushi Trivedi, Nirjharnee Nandeha, and Suneel Kumar Rathour. 2024. “A Review on Nanotechnology in Food Science: Functionality, Applicability and Safety Assessment”. Journal of Scientific Research and Reports 30 (6):876-83. https://doi.org/10.9734/jsrr/2024/v30i62105
69. Ayushi Trivedi, M. K. Awasthi, Nirjharnee Nandeha, Vinay Kumar Gautam and Mukesh Kumar Mehla. 2024. Addressing water security challenges through groundwater recharge for revival of Kanari River using AHP and geospatial techniques. Discover Water. Springer Nature. 4:59. https://doi.org/10.1007/s43832-024-00124-7
70. Nandeha N and Kewat ML. 2018. Evaluation of bio-organic preparations on yield of Sharbati wheat varieties under Kymore plateau and Satpura hill zone of Madhya Pradesh. International Journal of Current Microbiology and Applied Sciences 7(6):619-626
71. Nandeha N, Dewangan, YK and Sahu PL. 2016. Effect of crop geometry and nutrient management on yield performance of sweet corn (Zea mays l. Saccharata) under Chhattisgarh plain ecosystem. The Bioscan,11(4): 2293-2295.
72. Nandeha N, Dewangan, YK and Sahu PL. 2016. Response of sweet corn (Zea mays l. saccharata) under vayring crop geometry and nutrient management on nutrient uptake and economics under Chhattisgarh plain ecosystem. Progressive Research– An International Journal 11: 3738-3740.
73. Nandeha N, Sahu J and Sahu PL. 2017. Panchgavya: gift from the Indian breed cow. Progressive Research – An International Journal. Volume 12 (Special-I): 1070-1075.
74. Sahu H, GS Tomar and Nandeha N.2017. Effect of planting density and levels of nitrogen on yield and yield attributes of sweet sorghum (Sorghum bicolor L. Monech) varieties. International journal ofchemical studies. 6(1):2098-2101
75. Sahu PL, Chitale S, Nandeha N, Kurrey D and Kanwar PC.2015.Effect of different combination of organic materials and biofertilizers on growth and economics on scented rice (Oryza sativa L.) varieties.
76. Kumar R, Shrivastava S.K., Sahu P.L and Nandeha N., 2017. Efficacy of adjuvants on npv persistency against helicoverpa armigera (hubner) on tomato crop. Progressive Research – An International Journal. Volume 12 (Special-I) : 878-880
77. Gouthami Y., Tiwari N, Nandeha N, Dubey S, Singh P, Divyashree N., Ninama N. Climate Change Impact on Horticultural Crops: A Review. Int. J. Plant Soil Sci. [Internet]. 2023 Dec. 14 [cited 2025 Feb. 10];35(23):13-22. Available from: <https://journalijpss.com/index.php/IJPSS/article/view/4210>
78. Mani M. Pest management in horticultural crops under protected cultivation. Trends in Horticultural Entomology. 2022 Sep 16:387-417.