

National Conference on
**CLIMATE CHANGE AND
HORTICULTURE**
Impacts, Adaptation and Mitigation Strategies
(CLIMAHort - 2025)

18th & 19th September 2025



Edited by :

Dr. Y. G. Prasad | Dr. A. Bhagwan | Dr. P. Prasanth | Dr. Veena Joshi | Dr. G. P. Sunandini

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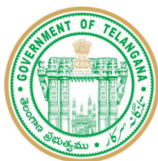
Sri Konda Laxman Telangana Horticultural University, Hyderabad
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Dr. Rajendra Prasad Central Agricultural University, Samastipur, Pusa, Bihar
NABARD, Regional Office, Hyderabad
Ministry of Earth Sciences, Govt. of India, New Delhi

ABSTRACTS

National Conference on Climate Change and Horticulture: Impacts, Adaptation and Mitigation Strategies

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Abstracts

CLIMAHort 2025:

Climate Change and Horticulture: Impacts, Adaptation and Mitigation Strategies

SKLTGHU, Mulugu, Hyderabad

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Foreword

It is a matter of great pride to present the Book of Abstracts of the National Conference on “Climate Change and Horticulture: Impacts, Adaptation and Mitigation Strategies”, being organized by Sri Konda Laxman Telangana Horticultural University (SKLTGHU) in collaboration with the Ministry of Earth Sciences, Government of India, the Department of Horticulture, Government of Telangana, Dr. Rajendra Prasad Central Agricultural University, Pusa and NABARD, Regional Office, Hyderabad on 18th & 19th September 2025.

Horticulture contributes significantly to India’s agricultural growth, nutritional security, employment generation and export earnings. The country has witnessed tremendous growth in horticulture sector in the last two decades and with the increasing income and changed life styles the demand for horticulture products is also on the rising side pressing for increased production and productivity. However, the increasing risks of climate change, extreme weather events, resource constraints and post-harvest losses demand immediate attention and innovative solutions to achieve the target. The conference brings together eminent subject specialists, researchers, scientists, policymakers, industry leaders, students and farmers to deliberate on climate-resilient strategies for sustaining and strengthening horticultural systems in eco friendly manner.

This Book of Abstracts consist of contributions pooled under six thematic areas of the conference, namely: impacts of climate change and extreme events on horticultural crops and their pollinators; methodologies for impact assessment including crop modelling; vulnerability, adaptation and mitigation strategies; socio-economic constraints in the adoption of climate-smart horticultural practices; policy and financial support to farmers to cope with multiple climate risks; and research advances and emerging technologies.

Together, these abstracts reflect the collective wisdom and innovative approaches of the scientific and farming community to address the pressing challenges of climate change in horticulture. I am confident that this compilation will serve as a valuable reference for researchers, students, policymakers and practitioners and will inspire collaborative efforts toward building a climate-smart and sustainable horticulture sector.

I extend my sincere thanks to all the contributors for submitting abstracts that are relevant and enriching to the theme of the conference. The efforts of the editorial team and publication committee in compiling and editing the abstracts is commendable.

My sincere appreciation goes to the Organizing and Advisory Committee and partner institutions for their dedicated efforts. I wish the National Conference a grand success with useful strategies for the benefit of farming community.


(D. Raji Reddy)

PREFACE

Sri Konda Laxman Telangana Horticultural University (SKLTGHU), established on December 23, 2014, is the only horticultural university in Telangana. The university comprises three constituent colleges, one Post Graduate Institute for Horticultural Sciences, three polytechnics, ten research stations and one Krishi Vigyan Kendra (KVK). It also includes one affiliated college—the Forest College and Research Institute—and one affiliated polytechnic. Accredited by ICAR, SKLTGHU offers a range of academic programs including B.Sc. (Hons.), M.Sc., Ph.D. and diploma courses in horticulture. The university maintains strong industry linkages, fostering student exchange programs and collaborative research initiatives. SKLTGHU undertakes location-specific research on fruits, vegetables, spices, floriculture, medicinal and aromatic plants, post-harvest technology and value addition, addressing the evolving needs of farmers across the state.

Sri Konda Laxman Telangana Horticultural University, Mulugu, Hyderabad in collaboration with Ministry of Earth Sciences, Govt. of India, Dept of Horticulture, Govt of Telangana and Dr. Rajendra Prasad Central Agricultural University, Pusa, is organizing a National Conference on “Climate Change and Horticulture: Impacts, Adaptation and Mitigation Strategies” on 18th and 19th September, 2025.

The conference focuses Climate change and extreme events and Impacts on Horticulture crops Methodologies for impact assessment ,Vulnerability Adaptation and Mitigation Strategies Socio-Economic constraints in adoption of Climate Smart Horticultural practices and Policy and financial support to farmers to cope with multiple climate risks.

The conference will be organising the discussions of about 153 abstracts in six major sub themes. Besides the conference also has special lectures, Invited and lead talks from eminent personalities in this field.

The organizing committee is extremely grateful to all the speakers and authors for contributing their abstracts and participating in the Conference. The contribution of all those who were involved in bringing out this “Book of Abstracts ” is gratefully acknowledged.

Editors

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Theme I

**Climate Change and Extreme Events:
Impacts on Horticulture Crops and their Pollinators**

Extreme Weather, Vegetation Vulnerability and Resilient Agricultural Planning: A Case Study of Telangana's 2023 Flood Event

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Climate change is intensifying the frequency and severity of extreme weather events, leading to catastrophic phenomena such as torrential rainfall, devastating floods, and rising temperatures. These events profoundly impact vegetation patterns, which serve as a critical proxy for understanding broader climatic shifts. Recent catastrophic floods across India—including in Uttarakhand, Himachal Pradesh, Kerala, Tamil Nadu, and Telangana—have caused severe vegetation loss and significant property damage. A striking example is the 27 July 2023 event in Telangana, where Mulugu district received 65 cm of rainfall in a single day. Satellite NDVI analysis revealed dramatic vegetation declines in flood-affected districts: barren areas (<0.2 NDVI) and sparse vegetation (0.2–0.4 NDVI) were reduced by 76% and 75.33%, respectively, while moderate vegetation (0.4–0.6 NDVI) decreased by 15.84%. This analysis complements a separate long-term (2000-2022) study on seasonal vegetation trends in Telangana using remote-sensed NDVI data and statistical methods such as the Mann-Kendall test and Sen's slope estimator.

The study found that during the Kharif season, 76.63% of the area exhibited positive vegetation growth, 22.49% remained stable, and only 0.88% showed decline. They are also useful for GKMS operational units in preparing impact-based crop weather forecasts and customized agromet advisories, contingency crop planning (including horticulture), adoption of mitigation practices, and promotion of short-duration horticultural crops during heavy rainfall by utilizing residual soil moisture for quick income generation. Overall, the study highlights that integrating NDVI-based vegetation monitoring with GKMS advisories can guide adaptive cropping strategies, reduce flood-induced losses, and enhance agricultural resilience under climate change.

Keywords: Climate change, Catastrophic floods, Telangana, Vegetation Vulnerability

Impact of Temperature Extremes on Pollination Biology of Horticultural Crops

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Pollination is one of the major factors for yield and quality in horticultural crops, with the reproductive phase highly sensitive to environmental fluctuations. Under climate change scenarios, temperature extremes like heatwaves and cold spells give a serious concern because they interfere with pollination processes like flower development, pollen viability, stigma receptivity, and pollinator activity. High temperatures during flowering accelerate flower senescence, reduce floral size, and diminish nectar secretion, lowering pollinator attraction. Heat stress also impairs pollen germination and pollen tube growth, while cold delays anther dehiscence and reduces viable pollen release. Such extremes can cause mismatches between pollen shed and stigma receptivity, decreasing fertilization success. Pollinator foraging behaviour is also temperature-dependent, with bees and other pollinators reducing activity during excessive heat or prolonged cold, further compounding pollination deficits.

In crops like apple, pear, and mango, unseasonal frosts or heat events during bloom can cause severe yield losses. In tomato, brinjal and capsicum, temperatures above 35 °C at anthesis result in pollen sterility and reduced fruit set, while in cucurbits, heat stress impacts both pollen viability and pollinator visitation. Adaptation measures include breeding for thermo-tolerant reproductive traits, adjusting planting schedules to avoid extreme temperatures during flowering, and using microclimate modification techniques such as shade nets, evaporative cooling, and windbreaks. Promoting pollinator diversity and habitat availability can also buffer against climate-induced disruptions. Understanding the physiological and ecological links between temperature extremes, floral biology, and pollinator dynamics is vital for developing climate-resilient horticultural systems. These insights are essential to maintain productivity and profitability amid increasing climatic variability and the rising frequency of extreme weather events.

Keywords: Pollination biology, Pollen viability, Horticultural crops, Climate change, Heat stress, Cold injury

Interactive Effect of Elevated Temperature and Soil Water Regimes on Growth and Yield Parameters of Capsicum: Field and Simulation

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Capsicum (*Capsicum annuum* L.), a cool-season crop, is increasingly cultivated under warm conditions and is susceptible to extreme temperatures. Climate change is projected to intensify temperature fluctuations and rainfall variability, which can negatively affect crop performance. The present research conducted at the experimental farm of the Division of Environmental Sciences, and CPCT, ICAR-IARI, from October 2022 to April 2023 aimed to identify the effects of temperature shocks and soil water regimes on the growth and yield of capsicum and optimize micro climatic conditions. In open field, plants were subjected to different temperature regimes with and without mulch, during first flowering to second harvest and second to fourth harvest. The same variety grown in green house was subjected to six different temperature and water regimes over ambient with mulch and without mulch. Greenhouse grown plants had higher LAI, TDM, cumulative fruit number and fruit weight (>80%) than the open field grown ones with highest in plants exposed to temperatures +3.5°C above the ambient with mulched conditions. Parthenocarpy was higher when minimum temperatures are <11° C. Capsicum yield adversely affected if the temperatures go beyond 35°C for a longer time, mainly during the reproductive phase. This study indicated that to grow capsicum successfully in open-field conditions, maintaining soil moisture (25-30% w/v) is crucial to reduce the effects of high temperature shocks. Field experimental data were used to calibrate and validate capsicum simulation model to simulate the performance of crop at different temperature and water regimes. The statistical indices such as R², RMSE, MBE and AI indicated that model could simulate the crop performance to satisfactory level with RMSE (g/plant) of 114.4, 31.29, AI of 0.97, 0.86 for fruit yield and TDM). In general, model performance was better for greenhouse grown capsicum. A total of 6160 combinations of micro climatic parameters were used to simulate the crop performance in greenhouse with seven different sets of PAR(320-800 μ mol m⁻² s⁻¹), five sets of CO₂ concentrations (400-800 ppm), 16 sets of maximum temperatures (-5 to +10°C from 25°C at 1°C step) and 11 sets of minimum temperatures (-0 to +10°C from 10°C at 1°C step). Based on the simulation results the best combination of microclimatic conditions to get the higher capsicum productivity in greenhouse are 700 CO₂ ppm, 350 μ mol m⁻²s⁻¹ PAR, temperatures of 32/13°C. These combinations increased the fruit yield per plant to about 2.5 times (4.59 kg/plant) than the current best conditions provide in the greenhouse, where the average fruit yield realized is 1.7 kg/plant.

Keywords: Capsicum, Temperature stress, Parthenocarpy, water regimes, TDM (Total Dry Matter)

Impact of $e\text{CO}_2$ (Equivalent Carbon Di Oxide) on Growth, Phenology and Physiology of Vegetable Cowpea (*Vigna unguiculata* L.) cv. Arka Garima

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Increase in CO_2 concentration affect plant growth and development, present study aimed to evaluate the effect of elevated CO_2 concentrations on the growth, phenology, and physiological responses of cowpea (*Vigna unguiculata* L.) cv. Arka Garima under open top chambers (OTC) which allows the regulation of CO_2 concentration under chambers. The experiment was conducted in a controlled environment with two CO_2 treatment levels: ambient and an elevated CO_2 concentration of 550 ± 50 ppm. The duration of the cowpea vegetative and reproductive phases was evaluated at the end of the experiment, and the numbers of pods per plant, average pod weight, pod yield per plant, and shoot fresh and dry matter weight were quantified. Results indicated that an OTC experiment shows that $e\text{CO}_2$ results in an increase in vegetative growth and reproductive productivity. The increase in the CO_2 concentration increases the number of leaves per plant, leaf area and earlier flowering and fruiting and growth enhancement under elevated CO_2 and its implications for crop productivity. Positive interactive effects of elevated CO_2 on different biochemical traits were also observed. Understanding the specific response of cowpea to $e\text{CO}_2$ in a particular environment is essential for effective crop management and adaptation strategies in the face of changing climate conditions.

Keywords: *Vigna unguiculata*, Arka Garima, $e\text{CO}_2$, climate change, phenology.

Assessment of Morphological and Biochemical Traits in Vegetable Pea (*Pisum sativum* var. *hortense* L.) Genotypes for Drought Tolerance in Eastern Sub-Himalayan Agro Ecology

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A field study was conducted to evaluate 28 vegetable pea genotypes under normal and drought-stress conditions to identify drought-tolerant lines based on morphological and biochemical traits. The experiment conducted on a randomized block design with three replications. Under drought stress, mean nodules per plant decreased from 12.7 to 6.4, flowering was delayed from 49.30 to 53.10 days, and maturity from 77.80 to 82.40 days. Plant height declined from 66.40 cm to 51.20 cm, and branches per plant from 3.80 to 2.40. Pods per plant dropped from 14.60 to 9.10, seeds per pod from 6.40 to 4.80, and seed yield per plant from 69.20 g to 41.60 g. Root length increased from 15.30 cm to 18.90 cm under stress, suggesting adaptive response. Among genotypes, RPCAU-23-5, Kashi Udai, Arka Chaitra, and KSP-110 exhibited superior performance under drought, maintaining >55 g seed yield, >10 pods per plant, and >60 cm plant height with enhanced root length (>20 cm) and stable nodulation. Kashi Nandini, the check, showed a 48% reduction in yield under drought. The genotypes Kashi Samridhi, RPCAU-23-17 and AP-1 showed highest drought tolerance. An increased content of Proline, catalase and peroxidase were observed indicating involvement in drought tolerance. The result indicated that some genotypes very under drought conditions can be utilized for further study and improvement.

Keywords: Biochemical, Drought, Morphological, Pea, Tolerance, Yield.

Climate Change and Extreme Events: Impacts on the Oil Palm Crop and its Pollinator

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Climate change and the increasing frequency of extreme events present major threats to global horticultural production systems, with oil palm (*Elaeis guineensis*), a vital plantation crop, being highly vulnerable. Rising temperatures, erratic rainfall, heatwaves, droughts and flooding directly influence the physiological processes of oil palm, including flowering, fruit set and oil yield. These stresses not only reduce productivity but also affect the overall quality of palm oil. A critical yet often overlooked aspect is the impact of climate variability on oil palm pollinators, particularly *Elaeidobius kamerunicus*, the primary insect pollinator introduced for effective pollination. Pollinator activity, survival and efficiency are strongly dependent on climatic conditions such as temperature, humidity and precipitation. Extreme events may alter their population dynamics, disrupt foraging behaviour and ultimately reduce pollination success, leading to significant yield losses. Furthermore, habitat degradation and reduced floral resources under changing climates exacerbate pollinator decline, compounding the problem. Addressing these challenges requires a holistic approach that integrates climate-resilient agronomic practices, pollinator-friendly management, conservation of biodiversity and breeding strategies for stress-tolerant varieties. Understanding the intricate interactions between oil palm, its pollinators and climate extremes is essential for sustaining productivity, ensuring ecological balance and securing future food and energy needs.

Keywords: Climate change, Oil palm (*Elaeis guineensis*), Pollinator activity, Sustainable productivity

Impact of Climate Variability Stress on Nectar and Pollen Dynamics in a Melittophilous Tree Species

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Climate change is intensifying the frequency and severity of droughts and heatwaves, placing substantial stress on flowering plants and their interactions with pollinators. Plant pollinator relationships rely heavily on floral rewards such as nectar and pollen, which are indispensable for pollinator nutrition and plant reproductive success. Bees, the dominant pollinators in most ecosystems, depend exclusively on nectar as their main energy source and pollen as their primary source of proteins and essential amino acids. Any reduction in these floral resources can therefore have cascading effects on bee health, foraging efficiency, and colony sustainability.

Abiotic stresses such as drought and supra-optimal temperatures directly influence floral physiology. Nectar production often declines under water stress, while its sugar and amino acid composition may shift depending on plant species and environmental conditions. Pollen is particularly sensitive, with stress affecting its development, viability, and nutritional value. These changes compromise bee nutrition, reduce pollination efficiency, and ultimately restrict fruit and seed production in plants.

Our study demonstrated that elevated temperature and water stress together significantly altered nectar and pollen dynamics in a melittophilous tree species. Reductions in resource availability at the flower level may compel pollinators to increase foraging effort to meet nutritional demands. Moreover, shifts in nectar and pollen composition can influence pollinator nutrition and foraging behavior, with potential consequences for colony health. From the plant perspective, such behavioral changes may lower pollinator visitation, reduce seed set, and decrease overall reproductive success. These findings highlight the importance of understanding how stress-induced modifications of floral resources affect both pollinator nutrition and plant reproduction. Such insights are critical for sustaining pollination services, biodiversity, and agricultural productivity under future climate scenarios.

Keywords: Melittophilous, Climate change, pollination services

Climate Change Impacts and Future Habitat Suitability of *Givotia rottleriformis*, an Endangered Dry-Deciduous Tree of Peninsular India

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Givotia rottleriformis (Euphorbiaceae), an endangered dry deciduous tree species of peninsular India, is highly valued for its lightweight wood traditionally used in the renowned Nirmal handicrafts of Telangana, which received a Geographical Indications (GI) tag in 2009. Despite its cultural and economic importance, the species is experiencing a severe decline in natural populations, largely driven by habitat loss, overexploitation, and the accelerating impacts of climate change. The present study aimed to assess the potential and realized niche of *Givotia rottleriformis* by modelling current and future habitat suitability using Maximum Entropy (MaxEnt) under Shared Socioeconomic Pathway (SSP) climate scenarios. Species occurrence records were integrated with the best environmental, topographic, and vegetation predictors to construct distribution models. Model performance was evaluated using the Area Under the Curve (AUC) metric(0.813) to ensure predictive reliability. Results indicated a marked contraction of suitable habitats under 2050 and 2070 climate projections, with fragmentation intensifying and persistence restricted to isolated refugia. The study highlights the urgent need for proactive strategies, including habitat restoration, assisted regeneration, and protection of climatically stable niches, to mitigate climate-driven range loss.

Keywords: *Givotia rottleriformis*, Species Distribution Modeling, MaxEnt, Climate Change, Habitat Suitability, SSP Scenarios, Conservation Planning.

The Compound Effects of Heatwaves on Floral Resources and Pollinator Populations

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Anthropogenic climate change is amplifying the frequency, intensity and duration of heatwaves, generating compound stressors that threaten critical plant-pollinator mutualisms. This review analyzes the multifaceted impacts of extreme heat events on horticultural crops (floral resources) and pollinator populations. Heatwaves induce acute physiological stress in flowering plants, reducing nectar volume and altering sugar profiles, while concurrently degrading pollen protein content and viability. Pollinators face parallel direct thermal stress, which often surpasses their critical thermal limits, leading to reduced foraging activity, homing failure, and increased mortality. For social bees, energy is diverted from colony growth to intensive hive thermo-regulation. The synergy of these pressures creates a feedback loop of resource depletion and pollinator decline. Crucially, heatwaves can drive phenological mismatches, desynchronizing peak bloom with peak pollinator activity. This decoupling directly threatens plant reproductive success manifesting in lower fruit set, quality, yield and undermines pollinator nutritional health, weakening resilience to other stressors. We argue that the compound nature of these impacts poses a greater threat than the sum of individual stressors, risking a potentially irreversible breakdown of essential pollination services. Safeguarding global food security therefore requires urgent adaptation strategies that integrate heat-tolerant crop varieties with microclimate management and pollinator-friendly habitat conservation to buffer these synergistic effects.

Keywords: Heatwaves, Pollination Service, Phenological Mismatch, Climate Change Adaptation, Pollinator Health.

Impact of Climate Change on Pollinators and Pollination Services in Horticultural Crops

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Pollination is a critical ecosystem service that underpins the productivity, quality, and sustainability of horticultural crops worldwide. It is crucial for food production and human livelihoods, and directly links wild ecosystems that many wild animals rely on for food and shelter with agricultural production systems. Without this service, many interconnected species inhabiting, and processes functioning within, an ecosystem would collapse. A large proportion of fruits, vegetables, nuts, and plantation crops depend on insect pollinators, especially bees, for successful fertilization and optimum yields. However, climate change poses a significant threat to pollinator populations and the stability of pollination services. Rising temperatures, unpredictable rainfall patterns, extended droughts, and increased frequency of extreme weather events disrupt pollinator behaviour, foraging activity, and reproductive success.

Phenological mismatches between flowering time in crops and peak pollinator activity are becoming increasingly common, leading to reduced pollination efficiency. In addition, habitat loss, altered floral resources, and the spread of pests and pathogens further exacerbate the vulnerability of pollinators. These disruptions have direct consequences on horticultural crop productivity, fruit set, quality, and market value, thereby threatening global food and nutritional security. Ensuring the resilience of pollination services under climate stress requires integrated strategies, including pollinator-friendly farming practices, habitat conservation, diversification of pollinator species, and the adoption of climate-smart horticultural technologies. Moreover, strengthening research on climate–pollinator interactions and promoting farmer awareness are essential to mitigate risks and sustain pollination-dependent horticulture. Addressing these challenges is crucial, as safeguarding pollinators under changing climates will not only ensure the stability of horticultural crop production but also support biodiversity, ecosystem health, and agricultural sustainability.

Keywords: Pollination, Climate-change, Horticulture, Production and Pollinators.

Adaptation Strategies for Pollinator Conservation in Horticulture

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Pollinators are vital for sustaining the productivity and quality of horticultural crops, with approximately 35-40% of global horticultural yields directly dependent on animal-mediated pollination. However, climate change induced stressors such as rising temperatures, prolonged droughts, altered rainfall patterns and increasing frequency of extreme events, combined with habitat fragmentation and pesticide overuse, have significantly disrupted pollinator populations and their ecological services. This poses a critical threat to food and nutritional security, particularly in fruit, vegetable and spice crops that rely heavily on efficient pollination. Adaptation strategies for pollinator conservation in horticulture involve both ecological interventions and technological innovations.

Ecological approaches include habitat restoration through floral resource diversification, conservation of wild pollinator corridors, integration of agroforestry and cover crops and reduction in pesticide load via integrated pest management (IPM). Technological strategies include the use of controlled pollination through managed honeybee (*Apis mellifera*) colonies, stingless bees and bumble bees development of climate-resilient pollinator species; application of digital monitoring tools such as remote sensing and IoT-based hive sensors and predictive modelling to synchronize crop phenology with pollinator activity. Furthermore, policy support through incentive-based schemes for farmers, pollinator-friendly certification systems and awareness programs strengthen adoption into local farming practices. A synergistic framework that combines conservation biology, precision horticulture and climate-resilient farming systems is essential to safeguard pollinator services and ensure sustainable horticultural production under changing climatic regimes.

Keywords: Pollinator conservation, horticultural crops, climate change adaptation, ecosystem services, sustainable horticulture.

Impact of Abiotic Factors and Mitigation Strategies in Vegetable Production

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A wide variety vegetables crops play a vital role in human nutrition but they are highly sensitive to erratic climate change. Abiotic factors like drought, flooding, salinity, increase in CO₂, extreme high temperature and low temperature can significantly impact on morphological, physiological and biochemical alterations in plants. Climate change effects severely on vegetables crops making it unprofitable by causing crop failures, yield shortages, quality declines and an increase in disease and pest incidence. These abiotic factors cause oxidative burst, membrane damage, decrease in chlorophyll content and photosynthesis rate as well as reduce the yield and quality of vegetable crops. Higher temperatures have a negative impact on soil moisture, extended droughts and can encourages the growth of pests and diseases. Plant growth and crop efficiency are reduced by cold stress, which significantly reduces productivity. Salinity stress creates water stress in plants and also negatively impacts membrane function, cytosolic metabolism, cell development and the production of reactive oxygen species (ROS). Adopting techniques climate-resilient cultivars and suitable crop management practices would significantly facilitate in mitigating the negative effects of abiotic factors. Mitigation strategies such as changes in planting dates, improved irrigation techniques, techniques for conserving moisture, the use of grafting technology, plant growth regulators, bio stimulants, green manure crops and protected cultivation can be used to overcome the abiotic stress to obtain sustainable the vegetable production and productivity.

Keywords: Climate, Abiotic, Drought, Temperature, Mitigation

Climate Variability and Its Impact on Mango Growth, Flowering and Yield in Telangana

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Mango crop thrive in regions characterized by low rainfall and low relative humidity during the stages of flowering, fruit setting, and harvesting, with warm to hot conditions prevailing during the fruiting period. For optimal growth, mango trees require substantial rainfall from June to September, followed by dry weather from the latter half of October onwards. Rainfall during the pre-flowering and flowering phases can delay flowering and promote in vegetative growth. The timing of various phenological changes in mango trees, including flowering and fruiting, is influenced by fluctuations of temperature and the transition between wet and dry seasons. To gain a comprehensive understanding of the impact of climatic conditions on flowering time and yield, an investigation was conducted at Fruit Research Station, Sangareddy as a part of ICAR-AICRP on Fruits program. This study aimed to collect data on climatic variability and its correlation with mango flowering and yield. The results from the period of 2015-16 to 2023-24 revealed a slight shift in the flowering date, which was linked to variations in rainfall and other climatic factors. Among the four selected mango cultivars (Suvarnarekha, Banganapalli, Totapuri and Mallika), Suvarnarekha exhibited the earliest flower initiation (December 1st Fortnight), preceeding Banganapalli (December 2nd Fortnight), Mallika (December 2nd Fortnight) and Totapuri (January 1st Fortnight) with 10-12 days in variability. Flowering time is a critical trait regulated by climatic conditions. The changes in rainfall distribution from June to October in 2024 (51 rainy days) and occasional drought conditions during the growing period led to staggered flowering among the selected cultivars.

Over the past 5-6 years, the date of fruit set was also influenced by climate, with extended rainfall in October and November causing a 15 days delay in fruit set for cvs. Suvarnarekha, Banganapalli, Totapuri and Mallika. This delay resulted in staggered fruiting and maturity, with multiple harvests occurring from April to July, extending the availability of mango fruits in Telangana state. Notably, yield data were significantly affected by climatic variations in flowering and fruit set. The highest fruit yield per tree (81.59 kg/tree) was recorded for cv. Totapuri in the year 2021-22, outperforming the other varieties. This trend aligned with the average fruit weight from 285-491 g among the selected varieties. Considering, the changing climatic conditions, temperature and rainfall play a dominant role in influencing the mango growth cycle, the timing and frequency of flowering, fruit development, as well as the taste and appearance of mangoes. These climatic factors need to be understood to ensure consistent mango production and quality.

Keywords: Mango cultivation, climate, Flowering time, Mango yield, Climatic variability

Survey-Based Insights on Vegetable Disease Dynamics in Telangana under Climate Change

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In Telangana, vegetable cultivation spans about 1.26 to 1.38 lakh hectares, producing 23.46 to 24.99 lakh metric tonnes annually, but this productivity is increasingly threatened by climate-driven shifts in disease epidemiology. Rising temperatures, erratic monsoons, and extreme rainfall are reshaping the disease epidemiology, making Telangana a hotspot. Viral diseases are the most sensitive to climate. Tomato and Chilli leaf curl, driven by whitefly surges at 30–35 °C with 55–65% relative humidity, have caused 40–60% yield losses, with >70% incidence recorded in Warangal, Khammam, and Karimnagar during Rabi 2019–21. Watermelon bud necrosis virus has intensified in Mahbubnagar and Nalgonda since 2015, coinciding with peaks in thrips at Tmax >34 °C. Papaya ringspot virus in cucurbits, causing 30–70% losses, has been consistently reported in Nizamabad, Adilabad, Medchal-Malkajgiri, and Medak from 2017 to 2022. Yellow Vein Mosaic Virus (YVMV) represents one of the most destructive diseases of okra in Telangana, with reported yield losses ranging from 50 to 80%, particularly when plants are infected at the early growth stages. The incidence and distribution of phytoplasma diseases are expanding. Brinjal little leaves, once 10–15%, reached >30% in 2023–24 surveys in Ranga Reddy and Nalgonda. Tomato big buds, previously sporadic, appeared more frequently in Karimnagar and Ranga Reddy after 2018, favored by warm nights (>20 °C) and humid post-monsoons.

Fungal and oomycete diseases also intensify under variable weather. Cucurbit downy mildew develops at 24–30 °C and >94% RH, causing 20–60% losses. Tomato early blight has increased since 2017 during wet spells, reducing yields by 25–40% in Ranga Reddy and Medchal. Chilli anthracnose, recurring in monsoons, caused a >30% loss in Warangal and Khammam. Gummy stem blight (*Didymella bryoniae*) has emerged strongly since 2020 in the cucurbits of the Nizamabad, Medak, Mahbubnagar, and Rangareddy districts, causing 20–40% losses. Tomato bacterial leaf spot is an emerging threat to Telangana tomato belts. Climate-smart disease management is key to sustaining vegetable crops and farmers' livelihoods in Telangana.

Keywords: Climate change, Vegetable diseases, Telangana, Viruses, Phytoplasma, Downy mildew, Anthracnose, Gummy stem blight

Papaya Under Climate Stress: Rising Disease Burden and Economic Consequences in Telangana

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Papaya is a high-value fruit crop in Telangana and is cultivated in semi-arid belts, such as Ranga Reddy, Sangareddy, Nalgonda, Yadadri and Mahabubnagar. Over the past decade, climate variability marked by rising maximum temperatures, erratic monsoons, and extended humid spells has altered the epidemiology of papaya diseases, particularly Papaya ringspot virus (PRSV), foliar spots, and postharvest rots. Between 2016 and 2022, there was a steady rise in the incidence of Papaya Ringspot Virus (PRSV) from 20% to 30% to more than 60% in several semi-arid districts. Peak outbreaks occurred from October to January, coinciding with periods of high aphid flight. Yield reductions of 25–70% were commonly observed, translating into direct farm-gate income losses of ₹0.6–2.0 lakh per acre. Postharvest assessments revealed an additional 10–15% fruit loss in wholesale markets during high-humidity periods, largely due to anthracnose and soft rot, further compounding grower losses. Profitability among papaya growers in Telangana has declined by an estimated 20–30% over the past decade, primarily due to escalating crop protection costs associated with increased disease pressure. Climate anomalies also amplify the risk of mixed viral infections and downgrade fruit quality grades, thereby reducing access to premium markets and exports. These findings highlight the dual biological and economic vulnerability of Telangana papaya under a changing climate. Integrating field epidemiology, vector monitoring, and value-chain loss assessments is essential for quantifying risks and designing climate-smart disease management strategies to sustain papaya production and farmer livelihoods.

Keywords: Telangana, Papaya Ringspot Virus (PRSV), climate change, disease epidemiology, economic impact

Impact of Long Term Rainfall Analysis or Rainfall Events on Flowering during Peak Mango Season

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Mango (*Mangifera indica* L.) flowering is a critical phenological stage that directly influences fruit yield and quality. Flowering in mango is highly sensitive to climatic cues, particularly rainfall patterns. This review synthesizes current literature to assess the impact of long-term rainfall trends and specific rainfall events on mango flowering during peak flowering seasons across tropical and subtropical regions. While moderate pre-flowering rainfall may support vegetative flushing and reduce water stress, excessive or ill-timed rainfall events particularly during panicle emergence and anthesis - have been consistently associated with adverse outcomes, including floral abortion, increased incidence of fungal diseases (e.g., anthracnose and powdery mildew), reduced pollinator activity, and poor fruit set. Long-term rainfall anomalies have further contributed to altered flowering phenology, asynchronous blooming, and exacerbation of alternate bearing tendencies. These shifts underscore the vulnerability of mango production systems to changing rainfall regimes under climate variability. The review also highlights adaptive strategies, such as chemical flowering induction, integrated disease management, and climate-informed agronomic planning, as essential tools for mitigating the negative impacts of rainfall during the flowering phase.

Keywords: Mango flowering, Rainfall variability, Climate change, Fruit set, Pollination, Alternate bearing

Molecular Characterization of Honey Bee Gut *Lactobacillus* with Probiotic Potential

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Honey bees are key pollinators for horticultural crops, and climate change is already stressing pollinator populations. The honey bee gut microbiota plays a vital role in nutrition, immunity, and resilience against environmental stressors. This study aimed to isolate, characterize, and identify bacterial strains from the honey bee gut to assess their functional and probiotic potential. A total of 7 bacterial isolates were obtained with probiotic potential, which were further characterized. Biochemical profiling (IMViC, nitrate reduction, DNase, gelatinase, and proteolytic tests) yielded negative results, while carbohydrate fermentation tests showed a broad ability to metabolize sucrose, dextrose, trehalose, lactose, mannitol, mannose, cellobiose, melibiose, inulin, and adonitol. All isolates demonstrated phenol tolerance and mesophilic growth at 25–35°C, but no growth at 45°C. Hemolytic assays confirmed γ -hemolysis (non-pathogenic nature), and antibiotic susceptibility testing indicated sensitivity to tetracycline, ciprofloxacin, gentamicin, and vancomycin, with limited resistance to ampicillin. Acid and bile tolerance assays revealed strain-specific survivability under simulated gastrointestinal conditions, supporting their probiotic potential. Molecular characterization using 16S rRNA sequencing identified the isolates predominantly as members of the genus *Lactobacillus*, with similarities ranging from 76.9% to 98.3%. Identified species included *Lactobacillus helveticus*, *L. crispatus*, *L. gasseri*, *L. casei* group, *L. selangorensis*, *L. guizhouensis*, and unclassified *Lactobacillus* sp. Strains. Overall, the honey bee gut harbors diverse *Lactobacillus* strains exhibiting safety, acid-bile tolerance, phenol resistance, and non-hemolytic profiles, indicating their potential applications in apiculture as probiotics for improving bee health and pollination efficiency, as well as in microbial biotechnology.

Keywords: Probiotics, Honey bee gut microbiota, *Lactobacillus* sps

Population dynamics of Thrips in Relation to Weather Parameters in Chilli

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Chilli is one of the major crops in Telangana, with a total cultivation area of 1.56 lakh hectares and an annual production of 7.94 lakh tonnes. The present experiment was conducted over four consecutive *Kharif* seasons (August- January) during 2021–22, 2022–23, 2023–24 and 2024–25 using the chilli variety LCA-625 at Vegetable Research Station, Rajendranagar, Sri Konda Laxman Telangana Horticultural University. The study aimed to understand the influence of weather parameters and climate variability on thrips populations in chilli. The results revealed distinct patterns in how environmental conditions shaped thrips dynamics. Importantly, the analysis underscores the potential implications of ongoing climate change and the increasing frequency of extreme weather events on pest behavior and crop health in chilli. Minimum temperature, evening humidity, rainfall, rainy days, wind speed and evapotranspiration emerged as critical factors in reducing flower thrips populations. Maximum and minimum temperatures were found to have significant negative correlations with thrips populations. High evening humidity conditions are unfavourable for thrips survival or activity, especially in flowers where microclimate effects may be stronger. Rainfall and rainy days both showed negative correlations with thrips populations. Wind speed and evapotranspiration were both negatively correlated with thrips. As climate change progresses, with rising temperatures, increased frequency of droughts, irregular rainfall and more extreme weather events, thrips dynamics in chilli crops are likely to shift significantly. Hence there is an urgent need for adaptive pest management strategies that incorporate climate resilience and microclimate monitoring, especially for high-value crops like chilli.

Keywords: Climate change, Chilli, Thrips population, Temperature, humidity, wind speed and rainfall

Effect of Weather on incidence of Purple blotch in Onion

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Red onion entries Bhima Red, Bhima Super, Bhima Shakthi and White Onion entries Bhima Shwetha and Bhima Safed were tested for the incidence of purple blotch in onion at Vegetable Research Station, Rajendranagar. Bhima Red, Bhima Super, Bhima Shwetha and Bhima Safed were tested during kharif, 2023 Bhima Red, Bhima Super, Bhima Shwetha and Bhima Safed and Bhima Shakthi during late kharif 2023-24, Bhima Shwetha and Bhima Shakthi during *rabi* 2023-24 as part of All India Network Research Project on Onion and Garlic. The incidence of purple blotch (PDI) was recorded on a scale of 0-5 (0: No incidence, 1:1-10%, 2:11-20%, 3:21-30%, 4:31-50% and 5:51-100%). All the tested entries showed purple blotch incidence during all the seasons. All the entries tested during *kharif* recorded a rating of 2 on a scale of 0-5, during late *kharif* conditions Bhima Red and Bhima Safed recorded a rating of 1 (1-10% PDI) and Bhima super, Bhima Shakthi and Bhima Shwetha recorded a rating of 2 (11-20% PDI) and during *rabi* season both the entries tested Bhima Shakti and Bhima Shweta recorded low incidence of purple blotch a rating of 1 (1-10% PDI) on a scale of 0-5. High amount of precipitation, higher relative humidity coupled with warm temperatures during *kharif* and late *kharif* seasons might have resulted in the greater incidence of purple blotch and promotion of higher disease development than in *rabi* with lower relative humidity.

Incidence of Phytophthora Leaf Blight in Colocasia under Telangana Climatic Conditions

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Colocasia (*Colocasia esculenta*) is an important tuber crop gaining importance in Telangana, cultivated over about 800 acres with an average productivity of 13.9 t ha⁻¹. It contributes to food and livelihood security through its edible corms and leaves, with steady demand and considerable potential for area expansion, due to less cost. However, its production is severely constrained by Phytophthora leaf blight caused by *Phytophthora colocasiae*. A roving survey was conducted in major Colocasia growing areas in Telangana during 2020–2024 under AICRP on Tuber Crops, Vegetable Research Station, Rajendranagar. The results revealed that percent disease incidence (PDI) ranged from 14.3 to 58.7% across major growing districts. The highest disease incidence (58.7%) was recorded in Vikarabad dist. The disease incidence is more when associated with excess rainfall (905–1220 mm), high relative humidity (>80%) and mean night temperatures of 22.1–24.8 °C during July–September. Yield loss assessments also indicated that early and severe infections reduced corm yield by 40–65%, while late-season infections caused <20% losses. The results indicated that congenial weather conditions such as excess rainfall, high relative humidity and moderate night temperatures favored higher disease incidence.

Impacts of Climate Change on Honeybee Colonies and Pollination Services in Horticultural Crops.

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Climate change and extreme weather events are primary drivers of honeybee colony stress, directly impacting pollination services essential for horticultural productivity. Globally, approximately 70–75% of horticultural crops rely on animal-mediated pollination, with honeybees contributing the major share. India maintains about 3.4 million managed honeybee colonies, predominantly *Apis mellifera* and *Apis cerana indica*, while non-domesticated species such as *Apis dorsata* and *Apis florea* provide essential ecosystem pollination. Climatic fluctuations, including rising temperatures, erratic rainfall, prolonged droughts, and cyclonic disturbances, reduce colony strength, disrupt foraging behavior, and increase susceptibility to brood diseases, resulting in compromised pollination efficiency.

Regional observations reveal altitudinal shifts in apple cultivation in Himachal Pradesh and reduced honeybee activity in mango orchards of Telangana and Andhra Pradesh under extreme summer heat, leading to lower fruit set and quality. Scientific beekeeping practices enhance colony resilience against climate-induced stresses. Key interventions include improved winter management to mitigate brood diseases, replacement with prolific young queens (2 years instead of 5 years) to sustain colony vigor, and supplemental feeding with sugar syrup enriched with novel antibiotics to combat abiotic stressors. Such strategies stabilize honeybee populations, maintain foraging efficiency, and ensure reliable pollination of climate-sensitive horticultural crops. Recognizing this, the All India Network Project on Vertebrate Pest Management (AINP–VPM), in collaboration with the National Bee Board (NBB), has conducted 10 specialized trainings to promote climate-smart apiculture practices. Given that climate is the foremost determinant of honeybee survival and activity, integrating climate-adaptive scientific beekeeping with pollinator conservation is essential to safeguard horticultural productivity, sustain pollination services, and secure food and nutritional security in India.

Keywords: Climate Change, Honeybees & Pollination

Effect of Climate Change on Pollination Behaviour of Vegetable Crops in India: A Review

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Climate change has emerged as a critical factor influencing pollination dynamics in vegetable crops across India. Rising temperatures, altered rainfall patterns, and shifting seasonal cycles are disrupting the synchrony between flowering periods and pollinator activity, leading to reduced pollination efficiency and compromised crop yields. Insect pollinators—particularly bees, butterflies, and flies play a vital role in the reproductive success of many vegetable crops such as tomato, brinjal, cucumber, and okra. However, climate-induced phenological mismatches and habitat degradation are threatening these interactions. Recent studies conducted in regions like Himachal Pradesh and West Bengal have documented significant declines in pollinator populations and changes in their foraging behavior. The International Centre for Integrated Mountain Development research revealed that reduced pollinator visitation has contributed to declining productivity in pollinator-dependent crops like capsicum and tomato. Additionally, findings from the Arid Forest Research Institute in Rajasthan highlight that temperature fluctuations are causing asynchronous flowering and insect emergence, resulting in lower pollen deposition and fruit set.

Insect pollination contributes an estimated US\$22.5 billion annually to Indian agriculture, accounting for 8.72% of total agricultural value. This underscores how vital pollinators are to food production. A study analyzing 45 years of FAO data revealed that yields of pollinator-dependent vegetable crops have stagnated or declined since 1993, while non-dependent crops showed no similar trend. This pattern suggests pollination limitation as a major factor. Field studies in West Bengal and Rajasthan have documented reduced pollinator visitation rates, especially in crops like tomato, cucumber, and brinjal. These declines are linked to temperature fluctuations, habitat loss, and agrochemical use. In several regions, farmers have resorted to manual pollination due to insufficient natural pollinator activity. This is labor-intensive and not scalable, highlighting the urgency of restoring pollinator populations. Despite India's rich biodiversity, only 5% of global pollination biology research originates from India. Long-term monitoring and ecological surveys are still lacking. Excessive use of pesticides and agrochemicals, Habitat fragmentation and land-use change, Climate change disrupting flowering-pollinator synchrony and Spread of pathogens and invasive species are the major drivers of pollination decline. These outcomes underscore the urgent need for adaptive strategies, including conservation of pollinator habitats, climate-resilient crop planning, and integration of pollinator-friendly practices in vegetable farming. Strengthening research on plant-pollinator interactions under changing climatic conditions is essential to safeguard India's vegetable production and ensure long-term food security.

Keywords: Climate change, Pollinators behaviour, vegetable crops

Mango cv. Banganpalli Phenological Responses to Weather Dynamics

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Climate and weather play critical roles in the economic success or failure of tropical fruit tree species including mango. Air temperature and rainfall influences vegetative and reproductive phenological phases in mango, which are the most important factors associated with adaptability and production of mango. The seasonal cyclic changes of growth in shoot, root, flower, fruit and their development depend on genotypic character of cultivars and climatic conditions. Varietal responses to the environment within and between mango cultivars account for their relative performance at different locations. Thus, phenological patterns are strongly under environmental control in mango. The timing of life-cycle events like flowering and crop maturity have only recently been considered as an area of climate impacts research in several crops. Under the influence of climate shift, early and delayed flowering is a characteristic feature of mango. With this objective, an attempt was made to understand the relation between phenology of mango cv. Banganpalli with weather dynamics especially temperature and rain fall under Telangana conditions (Sub topical and semi arid eco region).

Under optimum temperature for growth with non limiting nutrients and water, a mango tree produces vegetative buds continuously. In commercially cultivated matured mango orchards of south India bears 2-4 flushes during vegetative phase from July to October. After the cessation of the vegetative growth, mango undergoes dormant period coinciding with the low temperatures and subsequent induction of initiation of flower bud. Hence mango has distinct vegetative and reproductive phases. Mango cv. Banganpalli plants produces 4 vegetative cycles during vegetative phase (majority of vegetative flushes producing phase) which begins from 3rd week of July and continued to 3rd week of October (3 months) with overlapping the vegetative phenophases each other. Each vegetative flush cycle completes its cycle within 18-20 days depending upon the rain fall and mean temperatures. Among 4 flush cycles, first vegetative flush cycle starts at 21st July and ends at 10th August (19 days), second vegetative flush cycle begins from 13th August and ends at 5th September (23 days), third vegetative flush cycle begins from 7th September and ends at 26th September (19 days) and fourth vegetative flush cycle starts at 29th September and ends at 19th October (20 days). Among 4 vegetative flush cycles second vegetative flush cycle takes more number of days for completion of vegetative flush cycle (23 days, from 13th August to 5th September) during this period (from 24th August to 7th September) fall down of weekly mean maximum temperatures was recorded. This might be reason behind the slow growth rate or slower transformation of phenophases in such vegetative flush cycle.

Mango phenophase (319) underwent dormant for 61 days (21st October to 22nd December) based on highest scoring point at each point of time (at each data collection interval). Dormant phenophase (319) exposed to low temperature (<15°C) for 30-40 days and enters into flowering phase from 25th December to 13th March (78 days). 510 (closed flower bud) started during 3rd week of November and reaches to its highest scoring point on 25th December and remains in same phase up to 20th January (26 days) which is coinciding with low night temperatures (<15°C). Remaining panicle emergence and flower opening phases (511-617) undergoes quicker transformation within 33 days (from 21st January to 23rd February). Rising of weekly mean temperatures during this period from 21st January to 23rd February, which might be a reason for quick transformation of such flowering phenophases (511-617).

619 phenophase (fruit set) starts during 3rd week of February and reaches to highest scoring point at 24th February and remains in same phase up to 13th March. Rising in minimum temperatures (>15°C) (weekly mean) was recorded from 18th February which is coinciding with fruit set. There is a strong positive correlation between per cent of viable pollen and fruit set to mean night temperatures. This might be reason behind rising low temperatures coinciding with fruit set under present study. From 619 (fruit set) phenophase to 801 (fruit maturation) it takes 111 days in mango cv. Banganpalli in present study. A heat unit is an objective measure of the time required for the development of the fruit to maturity after flowering and can be measured by the degree days or heat units in a particular environment. The heat unit required for mango fruit maturity not only differs from cultivar to cultivar but also from place to place based on temperature of the locality. Even though the mean temperatures fall down during 1st April -10th April, quicker transformation observed from 703-705 phenophases (from 1st April to 10th April). This might be due to rapid cell division there by increased growth rate during 703 phenophase in present study.

Keywords: Mango, Banganpalli, Phenology and Weather dynamics

Impact of Climate Change on Native on Invasive Pest Species

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Climate change triggers pest outbreaks and habitat shift by altering the temperature, rainfall and CO₂ levels which accelerates pest development, expansion of wide range of geographical regions and increase plant vulnerability. In recent time the higher temperature and lower rainfall leads to outbreaks of invasive Coconut rugose spiralling whitefly (*Aleurodicus rugioperculatus*) by creating favourable conditions for coconut palms and it made rapid dispersal to new habitat like oilpalm. Rugose spiralling whitefly notably found in coconut, banana, mango and ornamental trees. This Rugose spiralling whitefly believed to be have originated from Central America, produces honey dew on infected leaves or plant parts eventually results in growth of fungi called sooty mould. However, this pest symptoms are invasive and become a serious pest of oilpalm. The pest which is common to both coconut and palmyra, found migrating to oilpalm. Its infestation in oilpalm causing yield losses upto 50% in its growing areas of Andhra Pradesh, Telangana in India.

Subsequently, this pest was reported to feed on many horticultural crops. Due to climate change which is creating conducive environment to the emergence and expansion by directly influencing their geographical range, life cycle, reproduction rate and indirectly weakens crops, impairing natural predators.

While, high temperature, high humidity correlates positively with whitefly population buildup. Therefore, rising temperatures enable pest to move into uninhabited areas like changed environment, less precipitation reduced precipitation rate and increased temperature which indirectly influencing the plant stress during growth and development period also alter pest plant-interaction and can reduce crop immunity which lead to significant challenges in crop expansion like oilpalm in Telangana.

To tackle this current management practices may not be effective in future. Hence, a holistic approach should be followed by exploring new pest management options or modification of existing practices *viz.*, developing climate resilient varieties, promotion of crop diversification, pest modeling to counter pest problems in a climate change scenario.

Keywords: Climate change, Invasive pest, Outbreak, Holistic approach

Resilience of Horticultural Crops and Pollinators Under Climate Change

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Climate change and the increasing frequency of extreme events poses significant threats to horticultural crops and their pollinators. Rising temperatures, irregular rainfall, droughts, floods and unseasonal frosts directly affect crop phenology, yield and quality. Heat stress shortens flowering and fruit-setting periods, while water stress influences fruit size, shelf life and nutrient content. Extreme weather also increases vulnerability to pests and diseases. It equally impacts on pollinators such as bees, butterflies and other insects, whose activity, foraging patterns and survival are disrupted by temperature extremes, habitat loss and altered floral availability. Declines in pollinator populations lead to reduced fruit set, poor seed formation and lower yields in pollination-dependent horticultural crops like cucurbits etc. Asynchrony between crop flowering and pollinator activity further limits effective pollination. To address these challenges, strategies such as developing climate-resilient varieties, adopting protected cultivation, conserving pollinator habitats, diversifying pollination services and integrating precision technologies are required. Strengthening pollinator-friendly practices ensures both sustainable horticultural production and ecosystem stability under changing climates.

Keywords: Pollinators, Asynchrony, Crop phenology, Vulnerability, Climate-resilient

Rainfall Variability and its Impacts on Horticultural Crops and Pollinators

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Rainfall variability, one of the most evident consequences of climate change, critically influences horticultural crop production and pollination services. Erratic patterns such as delayed monsoons, unseasonal showers, droughts and intense rainfall events alter flowering phenology, fruit set and crop quality. In many horticultural crops, excess rainfall causes flower drop, pollen wash-off and increased susceptibility to fungal and bacterial diseases, while deficit rainfall delays bud initiation, reduces nectar secretion and limits pollen viability. These stressors not only diminish yields but also affect the availability and quality of floral resources essential for pollinators. Pollinators, particularly bees and other insects, are highly sensitive to rainfall extremes. Prolonged wet conditions restrict foraging activity, damage nests and colonies and wash away nectar and pollen, while drought reduces floral abundance and continuity, causing nutritional stress and population decline. Such mismatches between crop flowering and pollinator activity weaken pollination efficiency, directly threatening reproductive success in fruit, vegetable and plantation crops. To mitigate these challenges, integrated strategies are needed, including rainwater harvesting, micro-irrigation, protected cultivation and adoption of climate-resilient cropping calendars. Establishing pollinator-friendly habitats, diversifying landscapes and conserving native pollinators can buffer rainfall-induced stresses and sustain ecosystem services. Strengthening research on rainfall pollinator crop interactions will be pivotal for designing climate-smart horticultural systems that ensure productivity, pollinator health and food security under changing rainfall regimes.

Keywords: Rainfall variability, Pollinators, Horticultural crops, Climate change and Adaptation

Theme II

**Methodologies for Impact Assessment
including Crop Modelling**

Methodologies for Impact Assessment of Climate Change on Crops through Modelling Approaches

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Climate change poses a significant threat to agricultural productivity and food security, necessitating reliable methodologies for impact assessment. Understanding how climatic variables such as temperature, rainfall, and elevated CO₂ influence crop growth and yield is critical for developing adaptation strategies. Among the available approaches, crop modelling has proven to be a robust tool for simulating crop responses under different environmental and management conditions.

Process-based models such as DSSAT, APSIM, WOFOST, and INFOCROP integrate weather, soil, and crop physiological parameters to predict growth dynamics, yield outcomes, and resource use efficiency. These models help in assessing the impacts of temperature rise, altered precipitation patterns, and extreme events on crop performance. Statistical and econometric models complement these simulations by analyzing long-term historical data to establish empirical relationships between yield and climatic factors. Additionally, integrated assessment models (IAMs) link climate models, socio-economic variables, and crop responses to evaluate regional vulnerability and long-term adaptation needs.

The incorporation of Geographic Information Systems (GIS), remote sensing, and downscaled climate projections has further improved the spatial and temporal accuracy of crop impact assessments. Such integrated modelling frameworks allow researchers and policymakers to identify vulnerable regions, evaluate adaptation options such as crop diversification, altered sowing dates, and efficient irrigation practices, and design targeted interventions.

Overall, crop modelling and complementary methodologies provide a scientific basis for climate-resilient agriculture. These approaches are indispensable for formulating evidence-based policies, supporting breeding programs for stress-tolerant varieties, and enhancing the adaptive capacity of farmers facing multiple climate risks.

Keywords: Climate change, Crop modelling, Impact assessment, DSSAT, APSIM, INFOCROP, WOFOST, GIS, Remote sensing, Adaptation strategies, Climate-resilient agriculture

Modelling the Future: AI-Integrated Crop Simulations for Climate-Resilient Horticulture

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Climate variability and extreme events increasingly threaten horticultural productivity, demanding robust methodologies for assessing impacts and designing adaptive strategies. Traditional process-based crop models such as DSSAT, APSIM, and INFOCROP have proven valuable for simulating growth, yield, and soil–water dynamics, but their accuracy is constrained by data gaps and difficulty in capturing complex crop–climate interactions. This paper highlights the role of AI-assisted modelling, where machine learning and deep learning algorithms are coupled with process-based models to enhance predictive accuracy and adaptability. AI is used to estimate missing variables (soil moisture, pest incidence), process high-resolution remote sensing data, and capture non-linear stress responses such as heat-induced fruit drop. Case studies show that hybrid DSSAT–AI models improved yield prediction in tomato and mango by 12–15% under heat stress, while AI-driven vulnerability mapping identified high-risk zones with greater spatial precision. Furthermore, AI integration extends crop simulations beyond yield to quality traits (Brix, acidity, shelf life) and enables near real-time decision-support systems for farmers. The findings demonstrate that coupling biophysical crop models with AI-driven analytics transforms static simulations into dynamic, farmer-centric tools for impact assessment, adaptive management, and low-carbon horticulture. Such innovations hold significant promise for building climate-resilient horticultural systems in India and beyond.

Keywords: AI-assisted modelling, crop simulation, horticulture, climate resilience, DSSAT, APSIM, INFOCROP

Machine Learning based Digital Soil Mapping of Soil pH and Organic Matter: A Methodology for Impact Assessment in Tamil Nadu

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Accurate assessment of soil resources is fundamental to evaluating agricultural sustainability and environmental impacts. Conventional soil analysis methods are limited by their labor-intensive nature, cost, and low spatial resolution, restricting their utility in large-scale impact assessments. To address these gaps, this study employed Digital Soil Mapping (DSM) integrated with Random Forest (RF) machine learning to predict soil pH and soil organic matter (SOM) across Tamil Nadu, India. Sampling density was optimized using Conditioned Latin Hypercube Sampling (cLHS), and the Boruta algorithm was applied to identify the most relevant covariates. Model optimization through grid search revealed that the best-performing RF configuration (2000 trees; mtry = 1) achieved Root Mean Square Error (RMSE) values of 0.60 for pH and 0.71 for SOM, demonstrating high predictive accuracy. Remote sensing indices were the most influential predictors for SOM, whereas terrain variables combined with spectral indices strongly influenced pH. The resulting high-resolution soil property maps provide spatially explicit insights into soil variability, enabling more reliable assessments of soil quality, nutrient status, and land-use potential. By enhancing the accuracy and scalability of soil information, this methodology strengthens the scientific basis for agricultural impact assessments and supports data-driven strategies for sustainable land management in climate-vulnerable regions.

Keywords: Digital soil mapping, Random Forest, Soil organic matter, Soil pH, Machine learning, Remote sensing, Impact assessment

Impact Assessment Methodologies with Emphasis on Crop Modelling

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Accurate assessment of the impacts of environmental change, agricultural policies, and technological interventions on crop production is essential for global food security and sustainability. Methodologies for impact assessment in agriculture increasingly leverage multifaceted crop simulation modelling approaches that integrate soil, plant physiology, climate data, and management practices. Crop models, including statistical, niche-based, and process-based types, are indispensable for quantifying interactions among environmental and agronomic variables, forecasting yields, and evaluating adaptation strategies under climate change scenarios. Process-based models such as DSSAT, EPIC, and others simulating dynamic soil-plant interactions provide robust spatial and temporal scaling predictions, often enhanced by ensemble modelling techniques and Bayesian model averaging to manage uncertainties.

Recent advances incorporate big-data analytics, GIS- based frameworks, and high-performance computing for finer-scale and more accurate impact assessment. Despite advances, key challenges persist regarding uncertainty quantification, data input quality, and the adaptability of models to new technologies and diverse agroecosystems. Continued interdisciplinary innovation in crop modelling methodologies is critical to improve decision-making for policymakers, agronomists, and producers under complex, evolving global conditions.

Keywords: Impact Assessment, Climate Change, Crop Modelling, Yield Prediction

Theme III

Vulnerability, Adaptation and Mitigation Strategies

Apical Rooted Cuttings (ARC) in Potato: A Climate-Smart Innovation for Sustainable Seed Production in Telangana

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Potato cultivation in Telangana is constrained by high seed costs, including handling and transport, dependence on seed imports from northern India, and lack of cold storage structures for seed storage. These challenges not only increase the cost of cultivation but also limit timely access to quality seed, making potato production vulnerable to climatic uncertainties. Apical Rooted Cuttings (ARC) have emerged as a climate-smart innovation, offering rapid multiplication of disease-free planting material, reduced seed costs, and improved adaptability under semi-arid conditions. ARC technology is particularly suited to regions like Telangana, where short growing windows and rising temperatures demand faster and more efficient seed production systems.

In varietal trials evaluating ARC of different cultivars with different spacings revealed that Kufri Chipsona at 40×30 cm produced the highest yield of 56.45 t/ha, followed by 54.00 t/ha at 30×30 cm, while K. Badshah and K. Karan showed optimal performance at closer spacing with 34.75 and 34.85 t/ha, respectively. A second study on 6 different varieties, Variety Kufri Fryom recorded the highest yield of 13.28 t/ha with superior tuber size (75.50 g large tubers), followed by Kufri Karan with 11.20t/ha yield. Across both experiments, ARC plants demonstrated good rooting, uniform stand establishment, and yields comparable to conventional seed tubers. The results validate ARC as a scalable, climate-resilient model for decentralized seed production in Telangana. By reducing dependency on external seed sources, lowering disease incidence, and enhancing yield efficiency, ARC technology holds strong promise for strengthening seed security, reducing production costs, and improving farmer incomes under changing climate scenarios.

Keywords: Potato, seed production, Apical Rooted Cuttings, Climate-Smart Agriculture

Future Climate Projections And Turmeric Vulnerability In Jagtial: Insights From Cmp6 And Field Survey On Extreme Weather Events

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Farmers in Jagtial predominantly cultivate the Erra Guntur variety of turmeric, a vital income source during the *khari*f season. However, climate change threatens its cultivation by altering rainfall patterns, increasing temperatures and intensifying extreme weather events, which reduce yields, lower quality and heighten pest and disease risks. Futuristic climate projections using CMIP6 models—BCC-CSM2-MR for rainfall and MRI-ESM2-0 for temperatures—were developed for Jagtial district for 2050 (mid century) under the SSP2-45 scenario. Results indicated a 49% increase in southwest monsoon rainfall (1254.1 mm vs. 840.6 mm) and a 58% decrease in post-monsoon rainfall (45.1 mm vs. 106.9 mm). Winter minimum and maximum temperatures are projected to rise by +5.4 °C (21.9 °C as against the normal 16.5 °C) and +1.5 °C (33.1 °C as against the normal 31.6 °C) respectively, indicating markedly warmer winters.

A 2024 survey of 90 farmers from Allipur, Itikyala and Raikal villages of Raikal mandal, Jagtial district revealed perceptions of more frequent heavy rainfall events, altered rainfall timing, prolonged dry spells, higher daytime temperatures and changes in sunshine hours. Meteorological data (1995–2024) from the Agromet Observatory, Jagtial, corroborated these trends, showing decadal southwest monsoon rainfall as 19.7% above the 30-year baseline, notable September–October temperature anomalies and excess July rainfall (+71.6% and +43.8% in consecutive weeks). Relative humidity has risen by 4–7% since September, intensifying pest and disease outbreaks. Heavy rainfall events (>65.5 mm) causing 2–3 days of waterlogging during the rhizome formation stage were linked to rhizome rot and leaf spot, with yield losses up to 56% per acre (90 quintals vs. 160 quintals normal). About 67% of farmers reported such losses, consistent with research showing that heavy rainfall and high humidity, combined with 3–5 days of waterlogging, favour pathogen growth. Hence, considering futuristic projections, climate-smart adaptations should definitely include raised-bed or ridge–furrow planting, seed treatment with *Trichoderma* or *Pseudomonas*, timely sowing to avoid peak heavy rains, adherence to weather-based advisories, mulching and neem cake application at 200 kg per acre to reduce disease incidence as per existing scientific research.

Keywords: Climate change, Turmeric cultivation, Extreme weather events, CMIP6 projections, SSP2-45 scenario

Harnessing Biostimulants as a Sustainable Input for Cultivation of Green Chilli (*Capsicum annuum* L.)

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Green chilli (*Capsicum annuum* L.) is an important spice-cum-vegetable crop in India and is widely consumed as a spice and food additive due to its color, pungency, flavor, and aroma, which is valued for its medicinal properties, being rich in antioxidants with anti-cancerous and analgesic effects. Despite its economic and nutritional importance, chilli cultivation faces major challenges such as soil nutrient depletion, abiotic stress, and excessive reliance on chemical inputs, which adversely affect yield and quality. In this context, sustainable approaches such as use of biostimulants are gaining attention for improving crop performance, resilience, and reducing environmental impacts.

A field experiment was conducted in a Randomized Block Design (RBD) with nine treatments including yeast hydrolysate, gluconates, humic acid, and seaweed extract at varying concentrations. Among all treatments, Yeast hydrolysate at 7.5 ml/L (T3) performed best, recording earliness to first flowering (31.5 days), maximum fruit count per plant (122.18), average fruit weight (8.09 g), fruit yield (32.93 t/ha), ascorbic acid content (89.00 mg/100 g), titratable acidity (0.21%), and capsaicin content (0.51%), followed by Seaweed extract at 5 ml/L (T8). The study concludes that yeast hydrolysate at 7.5 ml/L is the most effective biostimulant for enhancing growth, yield, and quality traits of green chilli. The results underscore the potential of biostimulants as sustainable inputs in chilli cultivation to optimize productivity, nutritional quality, and resilience under field conditions in Telangana.

Keywords: Biostimulants, green chilli, abiotic stress, yeast hydrolysate, seaweed extract, resilience

Advancing Crop Improvement under Climate Stress: Innovations and Applications of Speed Breeding

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The demand for high-quality and abundant food has intensified globally, driven by rapid population growth and exacerbated by climate change-induced stresses such as drought, heat, and flooding. These challenges have precipitated substantial yield losses and, in severe cases, global epidemics that jeopardize food security. Accelerating crop productivity and stability is now a critical goal for researchers and breeders. The generation time of most plant species remains a major bottleneck in the development of improved crop varieties. Speed breeding has emerged as a pivotal technology to address this limitation by enabling rapid generation turnover through regulated environmental conditions and extended photoperiods. This approach facilitates up to four to six generations per year in key crops like wheat, barley, chickpea, pea, and canola—outpacing conventional glasshouse or field breeding cycles.

Building on traditional shuttle breeding methods pioneered by Norman Borlaug, speed breeding now integrates advanced approaches such as marker-assisted selection, genomic selection, and the application of controlled environment agriculture (CEA) systems. Recent innovations include the use of LED lighting systems for optimal photoperiod control, automation and robotics for precise plant management, and the combination of speed breeding with gene editing technologies (e.g., CRISPR) to expedite trait improvement. Additionally, real-time phenotyping platforms and data analytics are enabling breeders to make data-driven decisions, enhancing the efficiency of selection processes. These advancements are transforming the landscape of plant breeding, offering sustainable solutions to meet the challenges of climate change and global food security. Recently, The World Vegetable Center's speed breeding facility in Taiwan has produced new climate-resilient varieties of pepper and tomato, focusing on heat tolerance and disease resistance—especially beneficial for smallholder farmers facing climate challenges.

Keywords: Speed breeding, climate resilience, controlled environment agriculture, genomic selection, gene editing, plant productivity

Developing Climate-Resilient Cucumber: Approaches and Strategies

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Cucumber (*Cucumis sativus* L.), an economically important crop and model plant for sex determination is highly vulnerable to climate change. Climate change, driven by greenhouse gases and ozone depletion, intensifies pest and disease pressure in cucumber. High temperature and drought are key constraints to cucumber productivity as among cucurbits, cucumber is the most drought sensitive vegetable crop, affecting its growth, reproduction and yield. Heat stress, determined by its intensity and duration, severely impacts crop performance as high temperature increases maleness in cucumber. Rising temperature and shifting weather patterns can also increase crop stress and enhance the spread of viral diseases by promoting virus replication and vector activity. Key pathogens such as cucumber mosaic virus (CMV), cucumber leaf spot virus (CLSV) and cucumber vein yellowing virus (CVYV) significantly reduce yield, threatening food security and farmers livelihood. Management strategies include integrated cultural practices and breeding for heat- and drought-tolerant genotypes and application of genome editing tools including RNA-based technologies specifically for virus resistance and hence for sustainable cucumber cultivation.

Keywords: Cucumber, heat stress, virus activity, genomic tools

Climate-Smart Postharvest Management of Okra: Integrating Crop Nutrition and Modified Atmosphere Packaging for Adaptation and Mitigation under Climate Change

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Climate change poses a critical challenge to horticultural production by intensifying postharvest losses, reducing quality and threatening food and nutritional security. Perishable crops like okra (*Abelmoschus esculentus* L. Moench) are particularly vulnerable to temperature fluctuations, rapid respiration and water loss, which shorten shelf life and increase waste. The present study evaluated an integrated approach combining climate-resilient crop management practices with Modified Atmosphere Packaging (MAP) to mitigate such challenges. A Factorial Completely Randomized Design was followed with 18 treatment combinations involving three levels of recommended dose of fertilizers (100%, 75% and 50% RDF) integrated with three organic modules, and two storage environments (ambient open storage and MAP). Results revealed that 100% RDF with Organic Module-1 under MAP (L₁M₁S₂) significantly reduced physiological loss in weight (0.62%), maintained higher ascorbic acid (14.72 mg/100 g) and chlorophyll content (1.05 mg/100 g) and extended shelf life up to 10.38 days compared to only 4.22 days under open storage with minimal inputs. While open storage accelerated ripening and soluble solids accumulation, MAP effectively delayed senescence and preserved nutritional quality. This integrated strategy highlights a sustainable adaptation pathway by reducing postharvest deterioration, enhancing produce resilience under variable climatic conditions and lowering food waste a key mitigation measure contributing to Sustainable Development Goals (SDGs) on responsible production and climate action. The findings provide a practical framework for climate-smart horticulture, supporting farmers and supply chains with improved profitability, resource efficiency and resilience to climate-induced postharvest stresses.

Keywords: Climate-smart horticulture, okra, integrated crop management, modified atmosphere packaging, postharvest resilience, food waste mitigation

Processing potato production under Future Warming Scenarios in India: Mitigation strategies

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Future climate change, especially rising temperatures, will have a major effect on processing potato crop. In this work, the potato planting dates for 2040–2069 (mid-future) and 2070–2099 (far-future) were optimized using the well-validated SUBSTOR–Potato crop model. The impact of climatic change on processing potato yields was also projected in this study. The future climate under two emission scenarios of the future, SSP2-4.5 and SSP5-8.5, was estimated using seven Global Climate Models (GCMs) from the Coupled Model Inter-comparison estimate phase 6 (CMIP6). The study concluded that, both the maximum and minimum temperatures were trending upward. Under the different climate change scenarios, it was discovered that the Leaf Area Index (LAI) and Tuber Initiation Days (TDAPS) had increased. In the absence of higher CO₂, tuber yields could decrease from 18.8% to 34.0%, depending on the circumstances and time frame. Conversely, in optimistic situations, yields might increase by 5.0% to 34.0%, while in gloomy scenarios, yields could increase by 11.1% to 28.0% due to rising CO₂ concentrations. Future temperature increases combined with higher CO₂ levels had a notable impact throughout the research area. However, it has been determined that the ideal planting window for obtaining the highest yield is to move the sowing date one week from the regular sowing date for Bihar, Uttar Pradesh, Madhya Pradesh, and West Bengal, and two weeks from the regular sowing date for Gujarat.

Keywords: SUBSTOR-Potato crop model, Climate change, Global climate model

Influence of Light Intensity on Growth and Adaptability of Ornamental Foliage Plants in Vertical Garden Systems for Climate-Resilient Urban Horticulture

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Climate change and rapid urbanization have led to shrinking green spaces, increasing the need for climate-resilient horticultural innovations that promote ecological balance and sustainable urban living. Vertical gardening has emerged as a promising adaptation strategy, enabling efficient utilization of limited space while mitigating the adverse impacts of rising urban temperatures, reduced air quality and loss of biodiversity. The present study evaluated the growth performance of three ornamental foliage plants *Philodendron erubescens*, *Syngonium podophyllum*, and *Pandanus veitchii* under varying light intensities in a vertical garden system. The experiment, conducted from November 2022 to March 2024 at the Floriculture Research Station, Rajendranagar, Hyderabad, employed a Factorial Completely Randomized Design (FCRD) with four light regimes: 250–500 lux (control), 500–1000 lux, 1000–1500 lux and 1500–2000 lux. Morphological, physiological and quality parameters including plant height, spread, leaf number, specific leaf area, survival rate, SPAD chlorophyll content and absolute growth rate were assessed at 90 and 180 days after planting. Results revealed that higher light intensities (1500–2000 lux) significantly enhanced plant growth and physiological responses, with *Syngonium podophyllum* showing superior adaptability under elevated light levels. These findings highlight the potential of vertical gardens as an urban climate adaptation and mitigation tool by optimizing light conditions and selecting climate-resilient plant species. This study underscores the integration of horticultural science with urban greening strategies as a pathway for enhancing sustainability, mitigating urban heat effects and promoting climate-resilient landscapes.

Keywords: Climate-resilient horticulture, vertical gardening, urban greening, sustainable landscapes

Mitigation Strategies for Coffee Yield Losses under Rising Temperatures

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Coffee is one of the most traded plantation crops worldwide, which is highly vulnerable to climate change, particularly rising temperatures and erratic rainfall. Elevated temperatures accelerate flowering and fruit ripening, leading to reduced bean size, poor quality, and yield decline. Moreover, heat stress predisposes coffee plants to pest and disease outbreaks, such as coffee leaf rust, which further threaten crop sustainability. In addition, changes in pollinator activity due to thermal stress impact fruit set and productivity. To counter these challenges, climate-smart strategies are gaining importance. Shade-based agroforestry systems are increasingly promoted to buffer temperature fluctuations, conserve soil moisture, and provide habitat for pollinators. Heat- and drought-tolerant coffee varieties are being developed through conventional breeding and molecular approaches. Improved irrigation scheduling, mulching, and organic amendments also help mitigate stress by enhancing soil health and water use efficiency. Diversification with intercrops such as spices and medicinal plants not only improves farmer income but also enhances ecosystem resilience.

Furthermore, predictive climate models and early warning systems assist farmers in making adaptive decisions. Adopting these integrated mitigation measures is critical to sustain coffee production and ensure quality in the face of rising climate uncertainties. Strengthening farmer capacity, promoting policy interventions, and investing in research will play a pivotal role in safeguarding coffee production systems, which are vital for rural livelihoods and the global economy.

Keywords: Climate change, Coffee, Yield loss, Mitigation, Agroforestry

Standardization of Nursery Technologies for Climate-Smart Turmeric (*Curcuma longa* L.) Cultivation

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Turmeric (*Curcuma longa* L.) is a high-value spice crop, faces significant challenges under climate change, including erratic rainfall, disease outbreaks, and high seed rhizome requirements. Conventional cultivation methods exacerbate these issues, prompting the adoption of standardized nursery technologies as climate-smart alternatives. This review synthesizes research on nursery-based systems such as pro-tray, miniset, and micro propagation, highlighting their agronomic and environmental benefits. Key findings demonstrate that optimized media compositions (Cair pith: vermicompost at 3:1) combined with pre-treatments (*Trichoderma* spp, bio-priming or fungicide dips) enhance seedling vigor, reduce disease incidence, and improve water-use efficiency. Pro-tray systems achieve 60 - 70 % seed savings and enable early monsoon synchronization, while miniset techniques offer rapid multiplication and resilience to climate shocks. Organic soil-less media and micro propagation further contribute to pathogen free, uniform planting material with lower greenhouse gas emissions. These methods collectively yield 15 - 25% higher productivity compared to traditional practices. However, adoption barriers include limited farmer awareness, upfront costs, and the need for region-specific adaptations. This review emphasizes the potential of nursery technologies to align turmeric cultivation with Climate Smart Horticulture (CSH) goals by reducing input dependency, enhancing resilience, and mitigating emissions. Future research should prioritize life cycle assessments, participatory trials, and capacity-building to scale these innovations effectively.

Keywords: Climate-smart agriculture, nursery technology, pro-tray system, miniset technique, bio-priming, resilience

Agricultural Adaptation in Severe Weather over Rajasthan and Value- Added Forecasting

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Rajasthan, is mainly characterized by its arid and semi-arid climate. During past years it has frequently experienced severe weather events such as droughts, heatwaves, cold waves, heavy rainfall, dust-storms, very heavy rainfall etc. posing serious challenges to agricultural production and food security. In this context, value-added forecasting has been prepared at the block level using inverse distance technique which integrates weather predictions from different models and the same is integrated with agricultural advisory. The block level forecast has emerged as a crucial tool for agricultural experts in providing impact- based advisories in respect of various crops and their current stage in the fields. By providing timely forecasts combined with actionable recommendations (e.g., on irrigation, sowing dates, pest control, preservation of stocks etc.), these forecasts have enhanced understanding of farmers in making informed decisions that reduce risk and has contributed in optimizing their yields among other factors. Furthermore, such forecasting enables early warning systems contributing to adaptation and mitigation strategies. As climate variability intensifies, enhancing the accuracy, accessibility, and usability of value-added forecasts will play key role in building resilient agricultural systems in Rajasthan.

Keywords: Heatwave, Heavy Rainfall, Coldwave, Adaptation

Climate Change Implications on Fruit Fly Incidence and Impact of Weather Parameters in Mango Ecosystems

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In recent years, climate change poses significant challenges in insect pests' incidence particularly in mango where fruit flies have emerged as one of the most destructive pests. Abiotic factors such as temperatures fluctuations, rainfall patterns and shifting of seasonal trends are creating favorable conditions for the population dynamics, distribution, severity and multiplication. A field experiment was systematically conducted for three consecutive years (2022 to 2024) in mango orchards located at Fruit Research Station (FRS), Sangareddy to monitor the fruit flies (Diptera Tephritidae) using pheromone traps. The key aim of the trial was to comprehensively examine the population dynamics of fruit flies and their response to variations in weather parameters. Fruit fly traps were strategically installed randomly at 20 no. in one hectare mango orchards. Weekly fruit fly catches was recorded and correlated with weather parameters. During 2022, peak fruit fly population was observed at 23rd SMW *i.e.* 06th to 12th June as 48.40 flies per trap. During 2023, peak fruit fly population was observed at 21st SMW *i.e.* 22nd to 28th May as 35.40 flies per trap. During 2024, peak fruit fly population was observed at 27th SMW *i.e.* 01st to 07th July as 48.45 flies per trap. The peak activity of flies coincides with the maturity and ripening time of fruits besides with the addition of abiotic factors. Three year mean data revealed that, fruit flies were active throughout the year and the population fluctuates at various time intervals ranging between 5.28 fruit flies per trap during 5th SMW to 47.15 fruit flies per trap during 22nd SMW.

The mean trap catches of male fruit flies recorded for three years was correlated with weather parameters and the analysis showed that there was a positive correlation with maximum temperature ($r = 0.47$), minimum temperature ($r = 0.70$), maximum humidity ($r = 0.02$), and rainfall ($r = 0.29$) whereas there is negative correlation with the minimum humidity ($r = -0.40$) with the variation of fruit fly population. Fruit flies trapped highlighted the intricate interplay between weather parameters and the population. Developing suitable models helps in forecasting the incidence. Present investigation would be helpful in the decision-making process for the safe and effective monitoring and management strategies to give information on fruit fly activity in the region to find out the incidence of fruit flies status. IPM and climate-resilient horticultural practices are crucial to safeguard mango ecosystems in long-term resilience.

Keywords: Fruit fly, Mango, Population dynamics, Weather parameters

Climate-Driven Dynamics and Integrated Management of Mango Dieback and Gummosis (*Lasiodiplodia theobromae*) in Telangana

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Mango (*Mangifera indica* L.), an important horticultural crop of Telangana State, dominates in both area and production but faces severe threats from climate-driven diseases like dieback and gummosis caused by *Lasiodiplodia theobromae*, a cosmopolitan soil-borne fungus affecting over 280 plant species. Over the past decade (2015–2024), Telangana's mango orchards have experienced increased disease incidence with extreme weather events - such as erratic monsoons, prolonged droughts and high temperature, exacerbating *L. theobromae* proliferation and infection rates. These climatic stressors weaken mango trees, enhancing susceptibility to gummosis (resin ooze from limb splits) and dieback, leading to rapid tree decline and significant economic losses.

A field experiment was conducted on disease affected Dashehari trees at the Fruit Research Station, Sri Konda Laxman Telangana Horticultural University, Sangareddy from 2022 to 2024 for evaluating an integrated disease management module under Telangana's climate-altered conditions. The results revealed that, a module including pruning of diseased branches, burning of infected material to reduce pathogen inoculum followed by spraying of Copper oxychloride (0.3%) or painting cut end of the stems with Bordeaux mixture, Soil application of Copper Sulphate (50–100g/plant) post-rainy season and a follow-up spray of Difenconazole (0.05%) 15 days later reduced disease severity to 10%, suppressed gum exudation, dieback and promoted new vegetative growth. Minimizing physical injuries to trees further lowered infection risks. These findings highlight the role of integrated management in mitigating the impacts of climate-induced disease dynamics, offering adaptive strategies to sustain mango production in Telangana's changing climate.

Keywords: Mango dieback, Gummosis, *Lasiodiplodia theobromae*, Climate change, Integrated Disease Management

Utilisation of Crop Wild Relatives (CWRs) of Vegetable Crops in Mitigating Climate Change and Ensuring Food Security

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Global food security is increasingly threatened by a range of challenges, including population growth, habitat destruction, climate change, water scarcity, limited arable land, and soil degradation. Over the past five decades, human activities have drastically reduced biodiversity, accelerating genetic erosion in crops and their wild relatives. The Food and Agriculture Organization (FAO, 2010) estimates that nearly 75% of crop genetic diversity has already been lost, posing a serious risk to agricultural resilience and long-term sustainability. Ongoing habitat destruction further exacerbates this issue by diminishing the genetic resources essential for food production and adaptation to shifting environmental conditions. Addressing these challenges is imperative to ensuring a secure and sustainable global food supply.

Approximately 400 species constitute the global diversity of vegetable crops, with the highest concentrations found in three key regions: tropical America, tropical Asia, and the Mediterranean. Within the tropical Asian region, India and China exhibit maximum diversity, with India's "Hindustani Centre" contributing nearly 80 native vegetable species alongside numerous wild and undomesticated types. India's extensive agricultural history is evidenced by Sanskrit nomenclature for introduced crops such as bottle gourd and watermelon from Africa, and onion from Central Asia, indicating pre-Christian Era plant material exchanges. The region supports widely distributed indigenous genera including *Trichosanthes* (snake gourds), *Momordica* (bitter gourds), *Coccinia* (ivy gourds), and *Canavalia* (jack beans) despite this remarkable diversity, commercial vegetable production globally focuses on only 20-25 crops, encompassing both indigenous and exotic species. This concentration highlights the contrast between available genetic diversity and current agricultural utilization patterns. Germplasm acquisition from within and outside country is the first step in germplasm management programme. A large germplasm representing a broad spectrum of genetic diversity has been introduced from other countries. This diversity represents both a valuable genetic resource and a foundation for food security in changing environmental conditions. Several introduced varieties have been used directly for large-scale cultivation. Many introductions in vegetable crops have also been used as parents to develop new cultivars. Germplasm of wild species of crops like brinjal (47), chilli (87), okra (82), tomato (385), water melon (18) have been introduced by NBPGR from abroad in the past few years. Besides identifying donors from cultivated form, their wild allies called CWR does have valuable genes with immense value for crop improvement and adaptation to changing environmental conditions. Utilization of CWR has enjoyed a great success in few crops like okra, tomato, potato & cucumber.

Mitigating Climate Change through Pre-Harvest Fruit Bagging in Mango (*Mangifera indica* L.) cv. Himayath

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Fruit bagging is an eco-friendly and climate-smart practice that protects mangoes from climatic aberrations, reduces pest and disease pressure and enhances fruit quality without heavy pesticide reliance. It acts as a simple adaptation strategy to produce clean, uniform and export-quality fruits under changing climate conditions. Climate change increases pest and disease incidence in mango (*Mangifera indica* L.) such as anthracnose, powdery mildew and fruit fly leading to high pesticide use. Pre-harvest fruit bagging is a climate-smart practice that improves fruit quality and reduces pest and diseases.

A field study at Fruit Research Station, Sangareddy, evaluated bagging in mango cv. Himayath with nine treatments *i.e.*, newspaper, reddish brown paper, butter paper, yellow paper, muslin, polythene, nylon, non-woven bags and control-non bagging. Reddish brown paper bags performed best, recording maximum fruit weight (809.03 g), TSS (23.07 °Brix), reducing sugars (7.60%), shelf life (13.67 days), highest 'L' (lightness) value (72.57) and 'a' (red) value (16.92) which improved fruit peel colour to golden yellow compared to control (L-68.59 and a-14.25) and an additional B:C ratio (3.54) was recorded when compared to control, while lowest ascorbic acid (31.15 mg/100 g) was also noted. In relation to the incidence of fruit pest and diseases, mealy bug incidence was highest in control (36.67%) followed by butter paper (16.67%), with no incidence in newspaper and reddish brown paper bag. Fruit fly was maximum in control (23.33%) and nylon bag (10.00%), absent in others. Anthracnose peaked in polythene bag (40.00%) followed by control (16.67%). Thus, fruit protection bags mitigate climate risks while ensuring sustainable, high-quality exportable mangoes.

Keywords: Pre-harvest fruit bagging, Himayath, Climate change and Export quality

Impact of Integrated Nutrient Management on Biomass Production and Carbon Stocks of Field Crops under Aonla (*Emblica officinalis Gaertn.*) based Agroforestry System in the Foothills of Himachal Pradesh

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The present study was conducted for two consecutive years, 2021–2023 at RHRTS, Jachh, Kangra (HP), India. The experiment followed a factorial randomized block design with three replications, assessing the performance of cereals (wheat and maize) and pulses (lentil and green gram) intercropped with aonla under varying distances (D) from tree trunks (D1: 0–1.5 m, D2: 1.5–3 m, D3: 3–4.5 m, D0: open) and eight nutrient treatments, ranging from control to integrated use of recommended dose of fertilizers (RDF), farm yard manure (FYM), and vermicompost (VC). Results revealed that tree-crop distance and nutrient management significantly influenced crop growth, yield, and soil health. Open conditions (D0) showed the highest growth and yield, followed by D3, while D1 showed the least. Nutrient treatment T6 (60% RDF + 20% FYM + 20% VC) consistently enhanced yield and economic returns across all crops. Lentil + maize + aonla exhibited the highest carbon sequestration, followed by wheat + green gram + aonla. SOC and available N and P were highest under T8 (100% FYM), while available K peaked under T6. Maximum soil pH, EC, and bulk density were observed in open plots and T2 (RDF). Economically, T6 and T5 with wider tree spacing (D3) were most cost-effective. Thus, intercropping cereals and pulses with aonla using integrated nutrient management (especially T6) at wider spacings offers optimal productivity and sustainability.

Keywords: Agroforestry, Integrated Nutrient Management, Carbon Sequestration, Productivity and Sustainability.

Impact of Climate Change on Vegetable Production and it's Mitigation

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Climate change is reshaping vegetable production more sharply than any other food sector, owing to the sensitivity of vegetables to microclimatic fluctuations. Rising temperatures shorten crop duration, reduce pollen fertility and alter sex expression in cucurbits, while heat stress in solanaceous crops leads to poor fruit set and quality loss. Irregular rainfall and extreme events disrupt soil-water balance, impair root aeration and trigger nutrient disorders. Elevated CO₂ increases vegetative growth but lowers micronutrient density, creating a hidden threat to nutritional security. Simultaneously, pest and pathogen ranges are shifting, with new biotypes emerging beyond current resistance strategies. Mitigation requires an integrated approach development of climate-resilient varieties and rootstocks, protected cultivation to buffer extremes, precision water and nutrient management and digital forecasting for pests and weather. Incorporating renewable energy, biochar and circular resource use can lower carbon footprints while sustaining productivity. Future-proofing vegetable systems lies in combining genetic innovations, ecological resilience and smart technologies to ensure both yield stability and nutritional quality under a changing climate.

Keywords: climate change, vegetables, mitigation

Role of Biochar in Climate Resilient Sustainable Horticulture in India

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Indian horticulture, contributing significantly to nutrition and farm income, is increasingly challenged by climate stresses such as drought, salinity, heat waves, and declining soil fertility. Biochar, a stable carbon-rich material derived from pyrolysis of crop residues and organic biomass, offers a climate-resilient solution for sustainable horticulture. Its porous structure improves soil organic carbon, buffers pH, water-holding capacity, nutrient use efficiency, and microbial activity, thereby enhancing crop growth, yield, and quality. Its highly porous, alkaline structure and rich carbon content give it unique abilities to improve soil health and buffer plants against climate stresses, while locking atmospheric carbon in the soil for long period. In tropical climatic regions like India, Brazil, Africa, SE Asia, etc., where soils are often acidic and nutrient-poor and droughts/heatwaves are intensifying, biochar application can boost productivity of fruit crops like mango, citrus, banana, grapes, and pomegranate, as well as vegetables such as tomato, chili, cucurbits, and leafy greens alleviates salinity stress, buffers drought effects, reduces nutrient leaching, and improves seedling vigour in nurseries. Beyond agronomic benefits, biochar also sequesters carbon, mitigates greenhouse gas emissions, and reduces reliance on chemical fertilizers, aligning with India's sustainability and carbon-neutrality goals. Integrating biochar with organic manures, mulches, and micro-irrigation presents a viable pathway for climate-smart horticulture. Thus, biochar adoption can enhance productivity, resource efficiency, and resilience while contributing to long-term environmental sustainability in Indian horticulture.

Keywords: Climate-resilient, Biochar, Sustainable Horticulture, Tropical climate, climate stress, Productivity, Carbon Sequestration

Influence of Pre-Pyrolysis Drying Methods on Biochar Properties: Implications for Climate-Smart Horticulture

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Climate change significantly threatens horticultural productivity by altering soil health, water availability, and nutrient dynamics. Biochar, a stable carbon-rich material produced by pyrolyzing biomass, offers a promising nature-based solution for both mitigation and adaptation. This study assessed the impact of three pre-pyrolysis drying methods—oven drying, sun drying, and shade drying—on the physicochemical properties of biochar derived from *Conocarpus erectus* woody biomass. Drying methods markedly influenced biochar quality. Sun-dried biomass produced biochar with enhanced surface area and higher nutrient content, making it suitable for nutrient management in horticultural soils. Oven drying resulted in biochar with greater carbon stability and higher fixed carbon, favoring long-term carbon sequestration and structural improvement of soils. Shade drying yielded biochar with increased porosity and water-holding capacity, providing significant benefits for horticultural systems prone to moisture stress. These findings highlight that pre-pyrolysis processing is not merely preparatory but a critical step in tailoring biochar for site- and crop-specific needs. Strategic use of biochar derived through optimized drying methods can enhance soil fertility, improve water-use efficiency, support microbial activity, and expand the adaptive capacity of horticultural systems. At the same time, the higher carbon stability associated with certain methods contributes to effective climate change mitigation. Thus, integrating drying-method-optimized biochar production into horticulture offers a sustainable pathway to strengthen both productivity and resilience under changing climatic conditions.

Keywords: Biochar, climate change, horticulture, adaptation, carbon sequestration

Endophyte based Biocontrol Strategies for Sustainable and Climate-Resilient Management of Anthracnose (*Colletotrichum capsici*) in Chilli

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Chilli (*Capsicum annuum*) represents a crucial agricultural commodity, highly valued for its economic and culinary importance, but its production is severely constrained by anthracnose (Fruit rot), caused by the seed-borne fungus *Colletotrichum capsici*, which leads to 50–80% yield losses and deterioration in fruit and seed quality. Conventional management strategies such as fungicides and development of resistant varieties are often limited by environmental conditions, pathogen resistance, and the extensive process of developing new varieties, highlighting the need for sustainable alternatives. In this study, healthy chilli plants were collected from anthracnose-affected fields across five districts of Telangana (Mulugu, Warangal, Khammam, Jayashankar Bhupalpally, and Mahbubabad), and 120 fungal and bacterial endophytes were isolated and screened in vitro against *C. capsici*. Ten isolates showing over 90% inhibition were identified through dual culture assays and molecular characterization, among which *Trichoderma* spp. (PEB 18) and *Bacillus* spp. (SEB 25) demonstrated 100% inhibition and were selected for seed coating of chilli variety LCA 334 using a compatible polymer.

Pot culture experiments were carried out with six treatments: T₁ – *Trichoderma* spp. (5 g Kg⁻¹ seed); T₂ – *Bacillus* spp. (5 g Kg⁻¹ seed); T₃ – combined *Trichoderma* spp. and *Bacillus* spp. (each at 5 g Kg⁻¹ seed); T₄ – fungicide control with Azoxystrobin (1 mL Kg⁻¹ seed); T₅ – pathogen control with *C. capsici* (5 g L⁻¹ inoculum); and T₆ – untreated control. Results showed that the combined treatment T₃ recorded the highest germination (82.25%), maximum seedling height at 30 days (15.06 cm), and zero mortality, whereas disease incidence was maximum in pathogen-inoculated (T₅- 80%) and untreated controls (T₆- 75%). These findings emphasize the potential of endophytes, particularly the synergistic use of *Trichoderma* spp. and *Bacillus* spp., as effective biocontrol agents, and adopting such biocontrol methods over conventional options will offer significant advantages for sustainable chilli cultivation and resilient agriculture.

Keywords: Chilli, anthracnose, *Colletotrichum capsici*, endophytes, biocontrol, sustainable agriculture

Horti-silvicultural Interventions for Climate-Resilient Podu Lands: Sustainable Pathways for Forest–Farm Integration in Telangana

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Shifting cultivation (Podu) in Telangana, practiced by tribal and forest-dependent communities, has resulted in recurring cycles of land degradation, soil erosion, and carbon stock depletion. These fragile landscapes, particularly in Adilabad, Komaram Bheem–Asifabad, Bhadradri Kothagudem, Mulugu and Khammam are increasingly vulnerable under climate change, where average temperatures have risen by 0.6–1.0°C and droughts and erratic rainfall are intensifying (IMD, 2023). This paper examines horti-silvicultural approaches as climate-smart pathways to transform degraded Podu lands into resilient, multifunctional landscapes. Integrating fruit crops—mango (*Mangifera indica*), guava (*Psidium guajava*), custard apple (*Annona squamosa*), tamarind (*Tamarindus indica*), and amla (*Emblica officinalis*)—with forestry species such as Pongam (*Pongamia pinnata*), Siris (*Albizia lebbek*), Shishm (*Dalbergia sissoo*), White teak (*Gmelina arborea*), Malabar neem (*Melia dubia*), Gliricidia (*Gliricidia sepium*), Subabul (*Leucaena leucocephala*), Chennangi (*Lagerstroemia parviflora*) and teak (*Tectona grandis*) offers a viable model. These combinations enhance soil fertility, improve water-use efficiency and can sequester carbon while diversifying sources of fruit, fodder, timber, and fuelwood. Beyond ecological restoration, such systems will demonstrate a rise in farm incomes compared to monocropping, while reducing pressure on natural forests. Additional co-benefits include biodiversity conservation, pollinator support and microclimate regulation—ecosystem services often neglected in Podu rehabilitation. The proposed framework emphasizes (i) vulnerability assessment of Podu ecosystems, (ii) adoption of tree–crop diversification with soil and water conservation measures, and (iii) policy convergence through Van Mahotsav, Green India Mission, NABARD and MGNREGS. Horti-silvicultural interventions thus represent a scalable, community-centric strategy for climate mitigation, adaptation and livelihood resilience in Telangana’s vulnerable tribal belts.

Keywords: Podu lands, horti-silviculture, climate resilience, carbon sequestration, Telangana

Litterfall Dynamics in Horticultural Orchards and Forestry Plantations: A Natural Pathway for Soil Fertility and Climate Change Mitigation

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Litterfall, a key component of nutrient cycling, plays a crucial role in sustaining soil fertility and enhancing carbon sequestration in both horticultural orchards and forestry plantations. The continuous deposition and decomposition of leaf, twig, and fruit litter replenishes essential nutrients, thereby reducing the dependence on synthetic fertilizers and lowering associated greenhouse gas emissions. On average, litterfall contributes 3–6 t ha⁻¹ yr⁻¹ of organic inputs in tropical orchards and up to 8–12 t ha⁻¹ yr⁻¹ in forest plantations, with significant potential to add 1–2 t C ha⁻¹ yr⁻¹ to soil organic carbon pools (Berg and McClaugherty, 2014; FAO, 2020). In horticultural systems, litter from perennial fruit trees such as mango, guava, and citrus not only improves soil nutrient availability but also enhances microbial activity and moisture retention. Similarly, forestry plantations of eucalyptus, casuarina, and teak contribute substantially to aboveground litter biomass, which upon decomposition supports long-term carbon storage. Integrating litterfall management with reduced external fertilizer application has shown 15–25% cost savings while maintaining or improving yields in perennial systems. This paper presents litterfall estimation as a climate-smart practice by (i) quantifying litter inputs in orchards and plantations, (ii) evaluating nutrient recycling efficiency and reduced fertilizer demand, and (iii) assessing the carbon sequestration potential of decomposed litter. Adoption of such nature-based strategies enhances ecosystem resilience, reduces production costs, and provides a sustainable mitigation pathway against climate change.

Keywords: Litterfall, nutrient cycling, soil organic carbon, horticultural orchards, forestry plantations, climate-smart management

Windbreaks, a Silvi-Horticulture System: Strategy for Climate Change Impact Adaptation and Resilience

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Windbreaks, a vital component of agroforestry, are recognized as multifunctional structural elements that enhance landscape functionality while offering diverse ecosystem services. They play a crucial role in protecting soils from wind erosion, regulating water and nutrient balance, improving biodiversity and natural pest control, and ultimately enhancing crop yield. In wind prone areas, they help in reducing the wind speed by 20 times its height on the leeward side and 5–10 times its height on the windward side, thereby minimizing crop damage. Beyond mechanical protection, they contribute significantly to microclimate regulation by reducing evapotranspiration, moderating temperature fluctuations, and conserving soil moisture. Yield analyses from no-till farming systems suggest that windbreaks not only compensate for yield losses due to land occupation but also enhance overall productivity, especially when aligned perpendicular to prevailing winds. An ideal windbreak would consist of double row of fast-growing tall tree species planted at central core, and next two rows of shrubs and small tree species which have muscular root are planted on both sides of the core. However, the form of trees changes throughout the growing period. It is essential to plant a number of species with different growth rates, form, architecture, shapes, and sizes. Few species of trees that develop quickly and are suitable for windbreaks are *Acacia nilotica*, *Azadirachta indica*, *Eucalyptus spp.*, *Casuarina spp.*, *Acacia torta*, *Anacardium occidentale*, and *Sesbania grandiflora*.

In Telangana, where horticultural crops occupy over 1.2 million acres and yield more than 5.3 million metric tons annually (2022–23), climate change poses serious challenges through rising temperatures, altered precipitation patterns, high wind activity, and pest infestations, adversely affecting flowering, fruit set, and crop maturation. There are several strategies proposed to enhance crop's resilience from susceptibility to climate change through climate resilient crop varieties, Climate smart horticulture, and Integrated Agroforestry Systems. In this context, integrating windbreaks as Silvi-horticultural systems serve as one of the efficient agroforestry practices for mitigating climate-related risks in large-scale horticultural systems. By mitigating climate-related risks and improving crop resilience, windbreaks stand as a practical, scalable, and sustainable intervention to safeguard productivity in Telangana's horticultural landscapes. Implementing diverse windbreak species can therefore act as a key strategy to improve crop resilience and productivity in a changing climate.

Keywords: Windbreaks, Silvi-horticulture system, Integrated Agroforestry System, Biodiversity, Climate smart horticulture, Telangana

Carbon Sequestration and Value-Added Wood Utilization in Horticultural Tree Species: An Integrated Strategy for Climate Change Mitigation

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Perennial horticultural tree species grown across Telangana, such as mango (*Mangifera indica*), mosambi (*Citrus limetta*), guava (*Psidium guajava*), sapota (*Manilkara achras*), pomegranate (*Punica granatum*), and tamarind (*Tamarindus indica*), hold significant potential in the fight against climate change. Throughout their lifespan, these species actively capture and store atmospheric carbon dioxide in woody biomass, roots, and soils, serving as natural carbon reservoirs. Quantifying this storage using approaches such as allometric modelling, biomass estimation, and soil carbon analysis enables the integration of horticultural plantations into national greenhouse gas inventories and carbon credit frameworks, linking climate benefits directly to farmer incentives.

The climate mitigation role of these systems continues beyond the orchard's productive years. Timber from senescent or unproductive trees often possessing favourable strength, durability, and aesthetic qualities can be transformed into durable products such as furniture, panels, and engineered composites. This post-harvest utilisation not only prolongs carbon storage but also generates additional income, creating a continuous cycle of ecological and economic benefits. Recognising horticultural landscapes as both living carbon sinks and renewable material sources allows for a holistic, circular bio-economy approach. Realising this vision will require enabling policies, targeted financial mechanisms, and farmer capacity building to ensure that horticultural systems contribute effectively to climate resilience and low-carbon development in South India.

Keywords: Carbon sequestration, horticultural tree species, wood utilization, climate-smart agriculture, bio-economy

Improving the Growth and Flower Yield of Pot Marigold (*Calendula officinalis* L.) under Varied Water Stress Conditions using Bio Inoculants”

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Water stress is a critical abiotic factor limiting crop productivity in arid and semi-arid regions. The present study aimed to assess the influence of bio-inoculants on growth, water relations, plant pigments, and flower yield of Pot marigold (*Calendula officinalis* L.) under varied water stress regimes, and to explore their potential in reducing irrigation frequency. A field experiment was conducted during 2020–2021 in a split plot design with four water regimes WS1 (field capacity), WS2 (75% field capacity), WS3 (50% field capacity), and WS4 (25% field capacity)— as main plots, and three bio-inoculants—AMF (Arbuscular mycorrhiza fungi), AMC (Arka microbial consortium), and control—as subplots, replicated thrice. The variety “Bon Bon Orange” was evaluated, and observations were recorded at 15, 30, 45, and 60 days after planting (DAP). Results indicated that WS2 produced the tallest plants (15.56 cm at 60 DAP), while AMF inoculation enhanced leaf dry mass (2.98 g at 30 DAP), leaf area index (17.41 cm²/g at 45 DAP), and leaf area duration. Higher relative water content was maintained in WS1 (66.91% at 45 DAP) and AMF (64.9%), whereas electrolyte leakage was lowest in WS2 × AMF (230.87 dSm). WS2 and AMF treatments significantly improved chlorophyll-a content and SPAD values, with WS2 × AMF recording the maximum chlorophyll-a (1.589 mg). Flower yield was highest in WS2 (39.33–56.67 flowers/plant) and AMF (38.25–57 flowers/plant). WS1 produced the greatest fresh biomass, while WS2 and AMF enhanced dry mass. Overall, WS2 (75% field capacity) in combination with AMF (20 g/plant) was most effective in improving growth, physiological traits, and yield of pot marigold, providing a sustainable strategy for optimizing production under limited irrigation conditions.

Keywords: Water stress, Bio-inoculants, *Calendula officinalis*, Arbuscular mycorrhiza fungi (AMF), Flower yield

Harnessing Biologicals for Climate-Smart Horticulture: The Soil First Pathway

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Horticulture, a major contributor to nutrition and farm income, faces growing threats from climate variability, soil degradation, and declining biodiversity. To sustain productivity and resilience, biologicals—including microbial inoculants, biofertilizers, biostimulants, and biopesticides—offer nature-based solutions that directly support climate mitigation and sustainable farming. The SoilFirst pathway, championed by SRIBIO, focuses on soil regeneration as the foundation of climate-smart horticulture. By restoring microbial diversity and soil organic carbon, it reduces dependence on synthetic inputs and lowers greenhouse gas emissions. Biologicals enhance carbon sequestration, nutrient efficiency, and abiotic stress tolerance while providing eco-friendly pest and disease management.

Field evidence shows that integrating SoilFirst with biologicals in fruits, vegetables, and plantation crops improves yields, quality, and farmer profitability while reducing the chemical footprint. This aligns with global sustainability priorities, including the UN SDGs, Climate-Smart Agriculture, and One Health frameworks. This presentation will showcase scientific insights, case studies, and scalable models demonstrating how biologicals and SoilFirst together can transform horticulture into a resilient, low-carbon, and sustainable production system

Waterlogging in Vegetables: Impacts and Innovative Remedial Techniques for Sustainable Yields

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Vegetable production faces significant risks due to waterlogging, which saturates soils and creates anaerobic conditions this resulting in oxygen deficiency compromises reducing in growth, yield and physiological vigour. Under waterlogged conditions, soils become hypoxic, impairing root respiration and nutrient uptake, and often leading to stomatal closure in C₃ vegetables. Common symptoms include chlorosis from nitrogen deficiency, stunted growth, and heightened susceptibility to root pathogens like *Phytophthora* and *Pythium*. To counteract the challenges posed by waterlogging, several morphological, agronomical and biological strategies have proven effective. Improved soil and crop management practices such as enhancing infiltration, drainage, and soil aeration which help to mitigate the detrimental impact of saturated soils. Additionally, selecting tolerant species and varieties, optimizing seedling production techniques, and applying plant growth regulators have shown promise in enhancing resilience to water stress, including waterlogging. However, specific adaptive morphological traits, such as adventitious root formation and aerenchyma development which enable certain species to tolerate such stress supported by hormonal signals such as ethylene and ABA, to survive oxygen-deficient environments.

Complementary precision strategies such as early planting, elevated cultivation platforms, and floating gardening systems offer contextual resilience. For instance, floating gardens in Bangladesh, constructed using water hyacinth and organic matter, provide a sustainable method for vegetable cultivation in flood-prone areas. This comprehensive toolkit fosters resilience, protects yield, and ensures continued productivity in waterlogged landscapes, making vegetable horticulture more robust in the face of increasing climatic extremes.

Keywords: Vegetables, Water-logging, Production, Techniques and Climate

Phenoclimatological Evaluation of *Musa acuminata* cv. 'Red Banana, AAA' under Middle Gangetic Plain of India"

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Musa acuminata cv. 'Red Banana, AAA' belongs to a specific group of edible bananas popular for its distinctive appearance, pigmentation, pulp colour and flavour. Traditionally it grows in parts of Andhra Pradesh along with the Southern parts of Tamil Nadu and Kerala. In 2022, 'Red Banana, AAA' was introduced in North-west Alluvial Plains of Bihar which is in the middle Gangetic plain of India. The experiment was taken up with different dates of planting for the secondary hardened tissue cultured plantlets. The plantlets were planted with five different time of planting in fifteen days intervals such as, 20th June, 5th July, 20th July, 5th August and 20th August under a replicated trial with five replications for each time of planting. The 'Red Banana, AAA' crop was evaluated with reference to different pheno-climatological attributes such as Growing Degree Days (GDD), Biologically Effective Degree Days (BEDD), Helio-thermal Unit (HTU), Photothermal Unit (PTU). The inter-relation of various phenoclimatological attributes with the bunch yield, fruit quality and disease-pest incidence were studied. Such a study provided a detailed scientific insight into the prospects of successful commercial cultivation banana cv. Red Banana, AAA' in North-west Alluvial Plains of Bihar. Further, the banana cv. 'Red Banana, AAA' may be evaluated across the state for generations of more scientific information.

Keywords: Red Banana, Pheno-climatology, GDD, BEDD, HTU and PTU

Enhancing Drought Resilience in Tomato through Integrated Approaches

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Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops grown worldwide, yet its productivity is highly vulnerable due to drought stress which is a major abiotic factor intensified by climate change. Drought adversely affects tomato growth and development by reducing cell expansion, impairing photosynthesis, disturbing nutrient uptake, and limiting reproductive success, ultimately leading to yield and quality losses. The severity of damage depends on the timing, duration, and intensity of water deficit, with critical stages such as flowering and fruit set being particularly sensitive. To cope with drought stress, tomato plants employ diverse morphological, physiological, biochemical, and molecular mechanisms. Morphological adaptations include deeper root systems, reduced leaf area, and increased cuticular wax deposition to minimize water loss. Physiological responses involve stomatal regulation, osmotic adjustment through the accumulation of compatible solutes like proline and sugars, with enhanced water use efficiency. Biochemically, tomatoes activate antioxidant defense systems to scavenge reactive oxygen species generated under water deficit, thereby protecting cellular integrity. At the molecular level, stress-responsive genes, transcription factors like DREB, NAC, WRKY, and signaling molecules such as abscisic acid (ABA) play pivotal roles in modulating drought tolerance.

Advances in genomics, marker-assisted breeding, and CRISPR-based gene editing are accelerating the development of drought-tolerant tomato varieties, while agronomic practices such as mulching, deficit irrigation, and the use of bio-stimulants complement genetic solutions. An integrated approach combining physiological understanding, molecular breeding, and sustainable water management is crucial to enhance drought resilience in tomato, ensuring stable production and food security under changing climatic conditions.

Grafting Studies on Tomato, Brinjal and Chilli with Different Solanaceous Rootstocks

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Climate change, characterized by unpredictable temperature shifts, irregular rainfall, and increasing soil-related stresses, has emerged as a serious challenge to the sustainability of horticultural crops. Among these, solanaceous vegetables such as tomato, brinjal, and chilli are highly vulnerable, as they respond sensitively to both biotic and abiotic pressures, resulting in lower yield stability and compromised quality. To overcome these limitations, grafting has gained prominence as an eco-friendly and climate-smart approach, enabling the combination of vigorous and stress-tolerant rootstocks with high-yielding scions for improved resilience. The present study was undertaken at the Centre of Excellence, Mulugu, during the spring–summer season of 2025, where 18 grafting combinations were evaluated. The experimental material comprised three rootstocks - MHTO 101 (tomato), *Solanum torvum* Sw. (brinjal), and EC 402105 (chilli) and six scions, namely Kashi Adarsh and Saaho (tomato), Shyamala and Nano (brinjal), and Byadgi Kaddi and EZ-H 1810 (chilli).

Detailed observations were recorded on germination behaviour, post-grafting success, physiological responses, and histological studies on union development. Among rootstocks, results revealed that MHTO 101 exhibited the highest germination percentage (95.5%) and reached grafting stage earlier than other rootstocks. With respect to graft success, *Solanum torvum* Sw. proved superior, achieving up to 90 per cent success along with quicker healing and faster readiness for transplanting. Physiological studies highlighted that compatible graft combinations of tomato, brinjal and chilli maintained higher leaf relative water content and stable chlorophyll levels under variable conditions. Histological analyses further validated these outcomes by demonstrating strong cambial alignment and continuous vascular connectivity in successful grafts, which are vital for efficient nutrient and water transport. Overall, the study emphasizes that careful rootstock selection enhances germination, seedling vigour, graft compatibility, and stress adaptability traits essential for climate-resilient horticulture. Thus, grafting in solanaceous crops emerges as a sustainable adaptation and mitigation strategy to reduce climate-induced risks, sustain productivity, and contribute to long-term food and nutritional security.

Keywords: Climate resilience, Grafting, Tomato, Brinjal, Chilli, Rootstock, Scion, Histology

Agroecological Innovations in Herb Cultivation

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Agroecological adaptation for herb cultivation emphasizes the application of ecological principles to develop sustainable and resilient farming systems in the face of climate change. Key strategies address soil and water management through practices such as contour hedgerows, drip irrigation, zero tillage and organic fertilization, which enhance soil fertility, improve water-use efficiency and reduce erosion. Crop diversification, including the integration of intercropping and agroforestry, promotes ecological stability, optimizes resource utilization and strengthens natural pest regulation. The cultivation of climate-resilient herb varieties drought-tolerant, heat-adapted or early-maturing cultivars further enables adaptation to erratic weather patterns and temperature variations. Integrated pest and disease management (IPM), based on biological and cultural approaches, reduces reliance on chemical inputs while improving ecosystem health and crop security. Moreover, participatory knowledge sharing, involving local farmers in co-creation and decision-making, ensures the integration of indigenous wisdom with modern practices, thereby enhancing context-specific solutions. Sustainable resource use, achieved through organic methods, precision agriculture and efficient input management, minimizes environmental footprints while maintaining long-term productivity. Together, these agroecological strategies improve ecosystem services, enhance resilience to climatic stresses and bolster farmers' autonomy. By fostering ecological balance and sustainable resource management, agroecological adaptation not only supports the viability of herb cultivation but also contributes to climate-smart agriculture and rural livelihood security. This holistic approach highlights the potential of agroecology as a pathway to sustainable herb farming in diverse agroecological and socio-economic contexts.

Keywords: Drip irrigation, zero tillage, soil fertility and organic fertilization

Integrative Breeding Strategies to Enhance Crops Resilience in Climate-Smart Agriculture (CSA)

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The agricultural yields is facing threats due to the global climate change and growing global demand for food production. Reducing Greenhouse Gas (GHG) emissions and ensuring food security are considered the greatest challenges in this century. Climate-smart agriculture (CSA) is a concept that can provide a solution and strategies to develop crops which can withstand to the unpredictable climatic events. The development of climate-proof crops, requires novel, stable, modern techniques and a multifaceted approach to obtain high productivity under unfavourable and adverse climatic conditions. The multifaceted approaches like advanced breeding technologies, biotechnological innovations, biostimulants, sustainable agronomic practices, and artificial intelligence (AI). Epigenetic regulation is crucial for plant stress resilience and reproductive development, as it modulates gene expression in response to environmental stimuli. New Genomic Techniques (NGTs) are a set of techniques that have emerged during the last 20 years and are used to alter the genetic material of an organism, NGTs include gene editing methods such as CRISPR-Cas9 gene editing, Transcription Activator-Like Effector Nucleases (TALENs), and Zinc Finger Nucleases (ZFNs) which enable the precise manipulation of genomes, facilitating Artificial Intelligence (AI) can be in optimizing phenotyping, omics, breeding strategies, predicting modeling, precise breeding and improving crop management practices to enhance reproductive resilience and ensure food security. Therefore, integrating mutli-faced strategies such as high-throughput phenotyping, genotyping, and modern gene editing, alongside artificial intelligence and speed breeding would help us meet sustainable resilient global food system.

Keywords: Climate-Smart Agriculture, New Genomic Techniques, Zinc Finger Nucleases and Artificial Intelligence

Role of Vegetable Grafting in Mitigating Abiotic Stress

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Vegetable grafting has rapidly emerged as a versatile and eco-friendly strategy to enhance crop resilience amid growing abiotic stresses and climate variability. This technique of uniting scion with vigorous, stress tolerant rootstock is increasingly applied to fruit vegetables such as tomato, cucumber, watermelon, eggplant, muskmelon, and pepper to combat challenges including salinity, drought, flooding, thermal extremes, heavy metal toxicity, pH imbalances, and nutrient deficiencies. Grafted plants consistently exhibit improved physiological attributes viz restricted translocation of toxic ions (e.g., Na⁺, Cl⁻), enhanced photosynthesis, better water and nutrient uptake and elevated antioxidant defenses; all contributing to growth stability, yield enhancement and improved fruit quality under stress. This technique circumvents slow conventional breeding, offering a rapid, sustainable alternative for developing climate-resilient vegetable varieties. Vegetable grafting stands out as a practical and scalable horticultural tool to mitigate multiple abiotic stressors, contributing significantly to sustainable productivity under evolving environmental pressures. Despite its effectiveness, successful implementation hinges on selecting compatible rootstock scion combinations and deepening mechanistic understanding to guide rootstock breeding.

Keywords: Vegetable, climate change, grafting and mitigation

Transforming Challenges into Opportunities of Climate Resilience in Plantation Crops

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The adoption of advanced technologies in plantation crops holds significant potential to enhance yields, thereby strengthening India's contribution to global food security. The development of high-yielding and climate-resilient varieties of coconut, arecanut and cocoa such as Kalpa Ratna, Kera Keralam, Shatamangala and VTLCH 3 has played a crucial role in improving productivity and tolerance to climatic stress. Integrated soil and water conservation methods: In cashew and coconut including the contour trenching with vetiver grass barriers, have effectively minimized runoff soil and nutrient losses while simultaneously augmenting soil organic carbon and microbial activity. These interventions not only improve soil health but also contribute positively to ecosystem stability and improved groundwater recharge. Collectively, these strategies highlight the pivotal role in advancing sustainable plantation management, ensuring farmer profitability and strengthening environmental resilience. To improve farm income and sustainability, multiple cropping systems such as coconut + black pepper, arecanut + black pepper + cocoa and oil palm + cocoa have proven highly profitable, yielding two to three times higher income while providing resilience in resource-stressed regions. Complementary soil and water management measures including mulching, rainwater harvesting, organic matter incorporation, bunding, terracing and conservation tillage further enrich soil fertility, enhance carbon sequestration and ensure long-term sustainability of plantation systems.

Keywords: Plantation crops, Climate-resilient varieties, Soil and water conservation, Multiple cropping systems and Farmer profitability

Assessment of IPM Practices as Climate-Smart Technologies for Sustainable Chilli Cultivation in Peddapalli District

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India is the largest producer, consumer, and exporter of chilli, contributing approximately 40% to the total global production, followed by China and Pakistan. The present study focuses on assessing the socio-economic impact of Integrated Crop Management (ICM) and Integrated Pest Management (IPM) practices in chilli cultivation in Peddapalli district, Telangana state. An ex-post facto research design was employed, with a sample size of 300 chilli farmers. Two mandals Mutharam and Mahadevpur were randomly selected from the district, and a total of six villages were chosen. From each village, 50 farmers were selected using a simple random sampling technique. All 300 farmers included in the study were adopters of IPM practices in chilli cultivation. The adoption of IPM practices showed a positive correlation with farmers' education levels and farm size. Moreover, farmers implementing IPM practices tended to have larger cultivated areas compared to those using traditional methods.

A majority of the respondents (65.33%) exhibited a medium level of adoption, followed by 25.33% with a high level of adoption of IPM practices in chilli. Notably, the adoption rate exceeded 85% in four recommended practices: 'Adoption of crop rotation' (87.00%), 'Application of Trichoderma before sowing & Application of neem-based products at early stages of pest infestation' (86.00%), installation of sticky traps & Pheromone traps (84.33%) and adoption of Mulching technology (74.33%). The cost of cultivation of chilli by adopting IPM practices across the selected villages Seetampeta, Kataram, Mahadevpur, Mutharam, Haripuram, and Brahmanapalli was ₹2, 59,188.98. The benefit-cost ratios in these villages were observed as 2.44, 2.32, 2.22, 2.45 and 2.20, respectively, highlighting the economic advantages of IPM practices over conventional methods. KVK, Ramagirikihilla has conducted Front Line Demonstration, Method Demonstrations, Trainings on IPM technologies to the farmers of selected villages to disseminate and improve adoption rate among the farming community. Overall, the study underscores the significant role of IPM in enhancing yield, profitability, and resource efficiency. It recommends the development and provision of suitable farm machinery, alongside effective extension support, to encourage wider adoption of these technologies. Furthermore, it suggests that government agencies and agricultural institutions should take proactive steps such as demonstrations, training programs, and awareness campaigns to promote IPM practices among chilli growers.

Keywords: IPM practices, Adoption Status, Crop Rotation, Pheromone traps, Adoption rate and Simple Random Sampling

Economic and Pathological Implications of Heat and Water Stress on Fruit Crops: Interactions with Disease Dynamics and Market Resilience

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Water stress, which is increasingly prevalent owing to climate change, represents one of the most significant abiotic constraints in fruit crop production, with cascading effects on disease dynamics and market resilience. Drought and irregular rainfall diminish plant vigor, impair fruit set, and alter microclimatic conditions, thereby increasing the host susceptibility to fungal, bacterial, and viral pathogens. In mango (*Mangifera indica*), water-deficit periods preceding panicle emergence are associated with higher anthracnose (*Colletotrichum gloeosporioides*) incidence, causing yield losses of 20–39% when unmanaged. Similarly, in pomegranate (*Punica granatum*), episodic drought followed by convective rainfall has been linked to severe bacterial blight (*Xanthomonas axonopodis* pv. *punicae*), with Indian reports documenting 60–80% yield losses during epidemic years, leading to sharp export disruptions. In grapes (*Vitis vinifera*), pre-monsoon water stress exacerbates powdery mildew (*Erysiphe necator*), raising input costs and reducing both fruit and wine quality. Citrus canker (*Xanthomonas citri* pv. *citri*) outbreaks in central and northeastern India are intensified under drought, with field trials showing up to 30% reduction in exportable fruit quality.

Understanding these biophysical impacts is crucial, as they lay the groundwork for the economic consequences. For instance, diminished yields as a result of these stresses not only affect plant health, but also elevate per-unit production costs, heightened disease management expenses erode farmer margins, and compromised fruit quality weakens export competitiveness. Following the discussion of disease dynamics, it becomes evident that market resilience faces its own set of challenges. Supply instability, price volatility, and the reduced capacity of smallholder farmers to absorb shocks are direct consequences of the earlier outlined biophysical and economic stressors. A clear, integrated approach is essential for effectively addressing these intertwined challenges. This approach should include water-smart horticultural practices, investment in disease-tolerant varieties, and the adoption of economic instruments like climate-indexed insurance and strategies for market diversification. Before delving into solutions, it is critical to understand how water stress serves as a central driver linking fruit pathology and economic vulnerability. An in-depth analysis reveals the urgency of interdisciplinary solutions to safeguard farmers' livelihoods and the stability of fruit value chains in a changing climate.

Keywords: Abiotic constraints, Climate-Indexed Insurance

Utilizing Artificial Intelligence-Based Systems for Biotic and Abiotic Stress Mitigation in Fruit Crops: Smart Farming for Sustainable Fruit Production

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Fruit crops have a significant potential for commercial cultivation because of their nutritional benefits and consumer demand. Fruits, being an impulse for nutritional security and economic growth, have been menaced by the changing global climate, as fruit crops are susceptible to a set of biotic and abiotic stresses that are amplified by climate change. Increased pest attacks, the spread of new diseases, and emerging abiotic stresses such as drought, salinity, temperature extremes, and nutrient imbalances lead to significant losses in yield and quality of the fruits by interrupting physiological processes, such as photosynthesis, water absorption, nutrient assimilation, and after harvest processes such as respiration, transpiration, and senescence. A yield loss of 20-39% was reported in mango, 60-80% in pomegranate, and 65% in banana. Traditional methods are ineffective against new climate-related challenges, such as large-scale monitoring of stresses and early detection of disease attacks, necessitating the use of advanced technologies, markedly artificial intelligence (AI), and machine learning to develop climate-resilient crops to improve productivity, thereby securing global food supply.

AI-based sensors and drones facilitate the early detection of stress and provide a targeted approach. Optimized irrigation systems supply water based on weather data, soil moisture levels, and crop water requirements. AI-based omics techniques help to identify stress-related genes, understand plant responses to stress, and identify DNA-based markers associated with stress responses. However, the use of AI-based systems in fruit crops faces numerous challenges owing to their complexity, cost of implementation, and lack of skilled personnel. Therefore, a thorough analysis and understanding of developments in AI-driven stress detection, predictive modelling, remote sensing, smart irrigation systems, and machine learning methods are necessary to integrate these systems in farming, which helps achieve precision and resilient farming of fruit crops for greater profitability and environmental sustainability.

Keywords: Climate change, biotic and abiotic stresses, artificial intelligence, drones, omics techniques

Rooting Resilience: Vegetative Propagation of Gum Karaya Tree Under Climate Threats

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Sterculia urens Roxb. is a keystone Non-Timber Forest Product (NTFP) species central to the livelihoods of tribal communities across India's dry forest regions. Its gum known as karaya gum is extensively harvested and traded for use in food, pharmaceutical, and industrial sectors, providing critical income to indigenous populations. However, climate stressors such as prolonged droughts, erratic rainfall, and rising temperatures coupled with overexploitation have severely degraded natural stands, threatening both ecological stability and tribal livelihoods.

The present study aimed to optimize vegetative propagation techniques under varying seasonal conditions using stem cuttings treated with Auxins Indole-3-Butyric Acid (IBA) and Naphthalene Acetic Acid (NAA) at 1000–3000 ppm. Results revealed significant seasonal influences, with rooting success exceeding 66% in spring season while the rainy season showed lower overall establishment, reflecting how climatic variables directly shape propagation success. By enabling large scale planting of *Sterculia urens* Roxb. through vegetative propagation, it helps ensure a sustainable supply of karaya gum a vital traditional income source for tribal harvesters. Furthermore, it enhances community resilience to climate change by preserving a multifunctional species that underpins local nutrition, health practices, and cultural traditions.

Keywords: *Sterculia urens*, vegetative propagation, climate change, conservation, auxins, seasonal variation

Effect of Organic manures and Bio fertilizers on Economics of kalmegh (*Andrographis paniculata* Wall. Ex. Nees.) var. CIM Megha

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Organic manures such as farmyard manure, vermicompost, neem cake, and poultry manure, essential for maintaining soil fertility and providing necessary macro and micronutrients, require significant investment of time, labor and financial resources. This is a critical issue for farmers, particularly small holder farmers who struggle with limited access to inputs and financial capital. In recent years, the use of bio fertilizers like nitrogen-fixing, phosphate-solubilizing, and zinc-mobilizing microbes has emerged as a breakthrough in low-cost, pollution-free input technology. These bio fertilizers have demonstrated positive effects on crop growth and yield besides protecting the environment by reducing chemicals local in soil. However, combining different bio fertilizers into a single formulation is challenging for farmers due to the lack of availability of such combined products in a single location. In order to address these challenges, the Arka Microbial Consortium (AMC) bio fertilizer was developed and released by IIHR, Bengaluru. AMC, which contains nitrogen-fixing, phosphorus and zinc-solubilizing, and plant growth-promoting microbes in a single formulation, simplifies application by offering a comprehensive solution.

The present investigation was carried out on kalmegh (*Andrographis paniculata* Wall. Ex. Nees.) var. CIM-Megha” during *Kharif* 2021 at College of Horticulture, Rajendranagar, Hyderabad in a randomized block design with 13 treatments by using organic manures in combination with AMC. Among the organic and bio fertilizer treatment combinations the results revealed that T₆: 75 % N through VC + 12.5 % N through NC + 12.5 % N through PM + AMC recorded the highest benefit cost ratio compared to other treatments due to organically grown products fetched higher price in market compared to inorganic produce, which helped the farmers by improving livelihoods gross returns, net returns and highest B:C ratio.

Keywords: Organic manures, Economics, kalmegh and sustainability

Recent Advances in Sustainable Climate Resilient Fruit Production

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India stands in second position as per the production of fruits in the world and production of fruit crops in India has surpassed 110 Million tons as per recent advance estimates 2024-25. Climate change is now a reality directly and indirectly influences growth, flowering, production and pre harvest quality of fruit crops. Promotion the cultivation of dry land fruit crops such as Aonla, Ber, Pomegranate, Bael, Custard apple and Fig overcoming moisture stress and sustain high temperature in arid and semi arid regions. In the climate change scenario, innovative and modern technologies like CRISPR-CAS, speed breeding, transgenics, genomics, biofortification, crop modeling, root stock breeding, fruit microbiome studies, artificial intelligence, machine learning OMICS techniques, climate resilient varieties and root stocks, artificial intelligence aided early warning predictions of droughts, floods, integrated farming approaches like Hortisilvipastoral and Agrihorti cropping systems, integrated soil, water and nutrient management strategies helps in sustainable fruit production. The recent achievements in climate resilient fruit production such as Mango hybrid Arunika has wider adaptability, pomegranate solapur Anardana has drought tolerance, Biofortified pomegranate variety Solapur lal, Arctic non browning Apple, Guava Arka Kiran has wider adaptability is tropical and sub-tropical regions and Mango root stock Sagarika tolerant to salinity has shown their potential in overcoming climate change.

Keywords: Fruit trees, Climate change and Recent advances

Climate-Smart Production Practices for Enhancing Yield and Quality of Guava cv. Allahabad safeda under HDP

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Climate change is intensifying production challenges in perennial fruit crops like guava, demanding for climate resilience interventions for sustainability. A field study was conducted at Fruit Research Station, Sangareddy on cv. Allahabad safeda under high-density planting system to evaluate for input use efficiency in Guava. The experiment was tested in four different combinations with raised bed cultivation, drip irrigation at 80% ER, fertigation at 75% RDF, mulching and micronutrient sprays (ZnSO_4 and Boric acid @ 0.2%) with Fe at 0.5% and Mn at 0.4% and compared with control. Among different combinations tried for the input use efficiency, the maximum fruit number (216.43), fruit weight (200.60 g) fruit yield (38.50 kg/tree), TSS (11.33 °Brix) and highest shelf life (7.81 days) was recorded in the combination of Raised bed + Drip irrigation (80% ER) + Fertigation (75% RDF) + Mulching + Micro nutrients spray (ZnSO_4 , Boric acid @ 0.2%, Fe @ 0.5% and Mn @ 0.4%) proving its effectiveness in enhancing the fruit productivity and resource-use efficiency for climate resilience interventions for sustainability.

Keywords: Climate, Guava, HDP and Mulching

Climate Change Impacts on Tea Production in India: Challenges and Adaptive Strategies

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Tea (*Camellia sinensis* L.) is one of the oldest and most widely consumed beverages worldwide, with India being the second-largest producer, contributing 22.7% of global tea production. Requiring temperatures between 10-30 °C, annual precipitation 1250 mm, and acidic, well-drained soils. Despite its economic significance, tea cultivation is highly sensitive to climatic conditions, including increasing CO₂ concentration, increasing temperature extremes, erratic rainfall, significantly affect crop growth and yield stability. There is an urgent need for adaptive strategies, including improved agronomic practices, climate-resilient cultivars, and integrated management approaches, to safeguard tea production and quality under changing climatic regimes. Future climate projections using global climate models (GCM) models suggest potential shifts in land suitability and productivity patterns across tea-growing regions.

Keywords: Temperature, Rainfall, Tea, Climate-resilient and Integrated management

Soil Microplastic Pollution in Horticulture: Impacts and Sustainable Mitigation Strategies under Climate Change

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Microplastic pollution in horticultural soils has emerged as a critical environmental concern, posing significant risks to soil health, crop productivity, and human well-being. The widespread adoption of plastic-based inputs in horticulture—such as mulching films, nursery bags, polymer-coated fertilizers, irrigation pipes, and wastewater irrigation—has contributed to increasing microplastic contamination. These persistent plastic particles interfere with soil biogeochemical cycles, disrupt microbial communities, and act as carriers for hazardous pollutants including heavy metals and persistent organic pollutants (POPs). In the context of climate change, soil microplastics further aggravate vulnerability by altering soil structure, reducing water infiltration, and impairing nutrient availability, thereby limiting the resilience of horticultural crops to heat and drought stress.

In India, rapid urbanization, improper waste disposal, and intensive cultivation practices have accelerated microplastic accumulation in productive soils. The long-term impacts extend beyond yield reduction, influencing nutritional quality of produce and increasing risks to food safety. Addressing this challenge requires the integration of sustainable mitigation strategies. Promising approaches include the use of biodegradable mulching materials, recycling and recovery of plastic waste, organic amendments such as compost and biochar to immobilize pollutants, and promotion of circular economy models in horticultural supply chains. Policy support, farmer awareness, and incentives for adopting eco-friendly alternatives are crucial to overcome socio-economic barriers. Systematic research on detection methods, crop modelling, and risk assessment is urgently needed to guide adaptive management. Tackling soil microplastic pollution is therefore essential for ensuring sustainable, climate-resilient horticulture and safeguarding environmental and human health.

Keywords: Microplastics, Horticulture, Soil health, Climate change, Sustainable mitigation, Circular economy

The Crisis of a Developing Nation: From Hunger to Hidden Hunger

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Hunger and malnutrition, often known as Hidden Hunger, are extreme expressions of suffering and poverty. Climate change is an important ongoing issue that significantly contributes to hunger and malnutrition by disrupting agricultural systems and reducing food production. Extreme weather events such as droughts, floods, and heatwaves damage crops, reduce yields, and affect livestock health, leading to food shortages. In the Global Hunger Index (GHI) 2024, India ranks 105th out of 127 countries, with a GHI score of 27.3, placing it in the “serious” hunger category. This underscores the urgent need for targeted interventions to combat hunger and malnutrition. India must prioritize on the horticulture sector in bridging this nutritional gap, as climate variability continues to disrupt staple crop yields, reduce dietary diversity, and impair access to nutrient-rich foods.

Fruits, vegetables, and legumes are key components of horticultural systems which are vital sources of essential vitamins and minerals. However, rising temperatures, unpredictable rainfall, increased incidence of pests and diseases, and declining soil fertility are directly threatening horticultural production. To address these challenges, there is a need to integrate climate-smart horticultural practices, improve post-harvest infrastructure (by increasing investments in cold storage, pack houses, and rural logistics to reduce post-harvest losses of perishable horticultural produce), and strengthen policy support (develop a national horticulture resilience strategy with a focus on climate-smart practices, develop climate-indexed insurance models tailored to horticultural risks, increase funding for agro-climatic research and breeding of resilient varieties via ICAR and KVKs etc.) to enhance resilience and ensure the year-round availability of horticultural produce. In this context, horticulture emerges not only as a vital tool for food security but also as a frontline strategy against hidden hunger in the face of accelerating climate change. These efforts can not only boost India's ranking in GHI but also bring us closer to Zero Hunger by 2030.

Keywords: Hunger, Climate change and Horticulture

Biofortified and Nutrient-Rich Vegetables: Farming Our Way to Better Health

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Micronutrient malnutrition or “hidden hunger,” affects billions globally, especially in developing countries where diets are calorie-sufficient but deficient in essential vitamins and minerals such as iron, zinc, iodine, and vitamin A. Traditional interventions like supplementation and industrial fortification, though effective, are constrained by high costs, supply chain challenges, and limited accessibility in rural and marginalized regions. Biofortification has emerged as a sustainable solution, enhancing the nutrient density of crops during their growth through conventional breeding, agronomic practices such as micronutrient fertilization, and modern biotechnological approaches including genetic engineering and genome editing.

Vegetables are highly suitable for biofortification due to their frequent consumption, short growth cycles, adaptability to diverse farming systems and significant role in daily diets. Varieties such as orange-fleshed sweet potato enriched with β -carotene, iron and zinc-fortified spinach, amaranth and vitamin A-rich carrots have shown measurable success in improving nutritional outcomes in vulnerable populations. These vegetables not only provide essential micronutrients that reduce the prevalence of anaemia, night blindness and other deficiency-related disorders, but also contribute to sustainable agriculture by integrating nutrition-sensitive practices into existing production systems. Biofortification of vegetables further offers social and economic benefits, empowering smallholder farmers, supporting women-led community nutrition gardens and integrating with public health initiatives such as school feeding programs and national nutrition missions. Scientific evidence shows that biofortified vegetables improve immunity, cognitive development and overall well-being, while also reducing dependence on industrial fortification and pharmaceutical supplementation. As a cost-effective, culturally acceptable and scalable intervention, biofortified vegetables are increasingly recognized as a critical pathway to address hidden hunger and enhance dietary quality worldwide.

Keywords: Biofortification, Nutrient-rich vegetables, Micronutrient malnutrition, Hidden hunger, Nutrition security

Harnessing Transcriptomics of Neem (*Azadirachta indica*) for Climate Change Adaptation and Mitigation

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Neem (*Azadirachta indica*) belongs to Maliaceae family, is often called as “village pharmacy”. It is a resilient multipurpose tree of tropical and subtropical regions and is gaining recognition as a critical species in the context of climate change. Its ability to withstand heat, drought, and marginal soils positions it as a natural candidate for climate adaptation strategies, while its roles in carbon sequestration, agroforestry, and bio-based pest management support global mitigation efforts. However, the increasing intensity of climate-induced stresses, such as prolonged droughts, temperature extremes, and shifting pathogen dynamics, poses challenges to its growth, productivity, and ecosystem services.

Advances in transcriptomic approaches provide powerful tools to dissect the genetic and molecular basis of neem’s stress tolerance mechanisms. High-throughput RNA sequencing enables the identification of stress-responsive genes, regulatory networks, and metabolic pathways associated with secondary metabolites that confer resilience and ecological benefits. Such insights not only deepen our understanding of neem’s adaptive responses to environmental fluctuations but also guide breeding and biotechnological interventions to enhance its resilience under future climates. Integrating transcriptomic data with ecological modelling and sustainable management practices can accelerate the deployment of neem as a climate-smart species, contributing simultaneously to biodiversity conservation, livelihood security, and carbon-neutral development pathways. As neem is an indigenous species and present abundantly in and around, the application of biotechnological interventions will enhance its ecological role and making it as climate resilient tree. Large-scale deployment of neem in agroforestry and urban greening can support carbon-neutral strategies while providing livelihood security.

Keywords: -Neem, climate change, adaptiveness, transcriptomics, climate resilient

Beyond Aesthetics: Climate Mitigation and Adaptation Potentials of Ornamental Plant Systems

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Traditionally associated with aesthetic and cultural value, floriculture is now emerging as a promising component of climate-smart Horticulture (CSH). Growing research indicates that ornamental plant systems can play a significant role in carbon sequestration, greenhouse gas (GHG) mitigation, and climate resilience. Recent case studies and literature highlight the potential of floriculture to contribute to sustainable, low-emission development pathways. For instance, rose cultivation in Bangalore has demonstrated increased soil organic carbon through the application of organic manures, aligning with findings that organic amendments can significantly enhance soil carbon stocks in intensive horticultural systems. In Telangana, the reuse of marigold waste from religious offerings into biofertilizers and natural dyes has mitigated methane emissions from organic waste decomposition, a strategy consistent with circular bioeconomy principles.

Urban floriculture also contributes to climate adaptation. Landscaping with ornamental species such as *Bougainvillea*, *Tabebuia*, etc in cities like Delhi, and Hyderabad has reduced urban heat island effects, supporting the role of green infrastructure in urban climate mitigation. Similarly, the protected cultivation of gerbera and carnation in some parts of India has improved yield stability under erratic rainfall while reducing nitrous oxide (N₂O) emissions—consistent with research advocating for controlled environment agriculture in CSA strategies.

Waste valorization remains a key area for reducing floriculture's environmental footprint. Converting floral waste into biochar, compost, and natural dyes not only prevents emissions but also aligns with carbon credit frameworks. Perennial ornamentals like bamboo and various palm species have shown high carbon sequestration potential, as documented in biomass carbon studies. Additionally, aquatic ornamentals like *Nelumbo nucifera* (lotus) contribute to phytoremediation in polluted water bodies, integrating ecological restoration with aesthetic value. Innovations in post-harvest handling, such as solar-powered cold storage have resulted in lower carbon footprints. These practices reflect the broader shift toward low-emission supply chains in floriculture, as emphasized in studies on energy-efficient greenhouse management. By aligning floriculture systems with CSH principles and circular bioeconomy models, there is significant potential to reposition the sector as a climate-resilient and economically viable enterprise.

Keywords: Ornamental plants, Climate-smart Horticulture (CSH), Greenhouse gas mitigation, Carbon sequestration, Soil organic carbon

Effects of Climate Change on Variability and Association of Brinjal Germplasm

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Climate change is one of the greatest challenges to sustainable crop production. Brinjal (*Solanum melongena* L.), being a major vegetable crop, is highly vulnerable to its impacts. Rising temperatures, erratic rainfall, prolonged droughts and increased pest outbreaks negatively influence brinjal flowering, fruit set and pollination efficiency, leading to considerable yield losses. In this context, the study on “Genetic variability, correlation and divergence for growth, yield and quality parameters in brinjal germplasm under Telangana conditions (2024–25)” provides valuable insights into identifying climate-resilient genotypes and trait associations that can be exploited for breeding strategies.

The study revealed high genetic variability among twenty-four germplasm for growth, yield and quality parameters, which is particularly important under climate stress. For instance, variability in plant height, spread and leaf traits such as leaf area and chlorophyll content demonstrates differential adaptation to microclimatic conditions. Genotypes like CHMB-12 and CHMB-16, with wider plant spread and higher branching, may be better able to withstand abiotic stresses by capturing more light and reducing heat injury. This “escape mechanism” is a crucial adaptation strategy in the face of high temperature episodes and erratic rainfall patterns. Correlation and path analyses highlighted that yield per plant is mainly governed by average fruit weight and number of fruits per plant traits less directly sensitive to short- term climatic stresses compared to flowering and plant height. Divergence analysis revealed substantial genetic distance among clusters, offering opportunities to combine complementary traits. Genotypes like CHMB-12, CHMB-01, CHMB-03, and CHMB- 14 can serve as parents in hybridization to create superior, climate-resilient brinjal lines. Thus, exploiting genetic diversity and selecting for stable, high-yielding and quality- enhancing traits can help buffer the adverse effects of climate change, ensuring sustainable brinjal production under increasingly variable environments.

Keywords: Genetic variability, Abiotic stress and Correlation analysis

Sustainable Biodegradable Packaging from Lemongrass Wastes

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The use of plastics in the horticultural supply chain, particularly from production, to packaging, transportation, and storage, has been driven for proper preservation of both perishables and durables. Plastics offer greater flexibility, transparency, weightlessness, high strength and durability. Plastics production relies on fossil fuels, which triggers greenhouse gas emissions and show severe environmental implications, leading to pollution and exacerbating climate change. Studies highlight the bridge between plastic production and climate change, emphasizing the need for sustainable alternative approaches derived from horticultural industrial wastes, to mitigate these impacts, the industries focus shifted to development of compostable as well as biodegradable packaging.

Compostable packaging films are sourced from agricultural crops and its wastes, majorly from maize. The widely available compostable packaging is PLA-PBAT based. Biodegradable packaging film is developed from lemongrass wastes obtained after extraction of essential oil. The lemongrass wastes possess high cellulose content which makes it ideal for biodegradable alternatives for petrochemical plastics. Cellulose nanocrystals were prepared employing acid hydrolysis method. The cellulose nanocrystals prepared (0.3%, w/w_{ch}) were immersed into the chitosan matrix (3%, w/3v) and mixed thoroughly to form a film forming solution with glycerol (12%, v/w_{ch}), which was later solvent casted to form thin films (41 µ). The developed films were tested for its functionality with no water vapour permeability, maximum transparency (81%), maximum tensile strength (64 MPa), elongation at break (6%) and puncture strength (19 N), respectively. The developed film degraded 62% in 15 days, upon soil burial tests.

Keywords: Horticultural supply chain, Sustainable packaging, Biodegradability studies

Sustainable Horticultural Supply Chain Management for Climate Change

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Climate change poses significant challenges to the horticultural supply chain, including erratic rainfall, temperature fluctuations, extreme weather events, and disrupted logistics, largely driven by excessive fossil fuel use and greenhouse gas emissions. Mitigation strategies focus on climate-smart interventions such as integrating renewable energy (solar, wind, and biomass) for cold storage, refrigerated transport, and post-harvest operations, employing electric vehicles and optimized routing, adopting sustainable packaging, including biodegradable and smart systems, and using AI-driven tools for predictive weather forecasting, yield prediction, and supply chain optimization. Waste valorization, such as converting temple and market flower residues into compost, biochar, or natural dyes, further reduces emissions while promoting circular economy approaches.

Case studies highlight the impact of these strategies: marigold, rose and other waste recycling in Telangana prevented methane release, vertical farming reduce transportation-related carbon footprints by 50% and solar-powered cold storage in Assam and Bihar, improved post-harvest management decreased non renewable fuel usage. Jivabhumi's AI-based supply chain platform Foodprint, based in Bengaluru, enhances climate resilience in horticulture by providing real-time insights on weather patterns, pest risks. By integrating blockchain and AI, it ensures traceability and efficient logistics, reducing post-harvest losses and greenhouse gas emissions in the supply chain. Collectively, these interventions, supported by AI and renewable energy integration, enhance supply chain resilience, reduce environmental impact, and improve production stability, demonstrating that the horticultural sector can effectively adapt to climate change while contributing to sustainability and carbon mitigation.

Keywords: Supply chain, Climate Change, Mitigation Strategies

Climate-Resilient Fruit Cultivars: Safeguarding Environmental Sustainability in Horticulture

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Climate change poses unprecedented challenges to global horticulture, with fruit crops being particularly vulnerable due to their perennial nature, long gestation period and sensitivity to temperature, precipitation and extreme weather events. The identification and deployment of climate-resilient cultivars represent a cornerstone adaptation strategy to safeguard productivity, quality, and farmer livelihoods under changing agro-climatic regimes. Recent advances in genomics, phenomics and crop modelling have enabled precise characterization of genotype $\times$ environment interactions, facilitating the development of cultivars resilient to abiotic stresses such as heat, drought, salinity and erratic rainfall, as well as biotic pressures exacerbated by shifting climates. For instance, mango, citrus, banana and grape breeding programs are integrating physiological resilience traits with molecular markers for accelerated selection. Simultaneously, the utilization of wild relatives, landraces and underutilized fruit species offers untapped genetic reservoirs for resilience breeding.

Climate-smart horticulture also emphasizes region-specific cultivar recommendations, supported by multi-location trials, decision-support tools and participatory breeding approaches involving growers. Beyond yield stability, resilient cultivars contribute to enhanced carbon sequestration, resource-use efficiency and nutritional security, aligning with mitigation strategies. The integration of traditional breeding with cutting-edge biotechnological interventions, including CRISPR/Cas-mediated genome editing and transcriptome-assisted selection, further accelerates resilience breeding pipelines. This abstract highlights the role of climate-resilient cultivars as a pivotal adaptation strategy in fruit crops, emphasizing their contribution to sustainable horticultural production systems under climate uncertainty. Strengthening collaborative networks, policy frameworks and farmer-centric dissemination models will be essential to ensure scalable adoption and long-term resilience of fruit-based farming systems.

Keywords: Climate-resilient cultivars, climate change, Fruit crops, Genotype $\times$ Environment interaction and climate-smart horticulture

Speeding up Breeding Cycles by Manipulating Plant Growth a Strategic Approach to Mitigate Climate Change

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The world population is projected to reach 10 billion by 2050, and the expected demand for food will increase significantly. It will be necessary to develop new cultivars while minimizing the environmental damage caused by agriculture and sustaining higher yields. The length of the breeding cycle in conventional breeding methods for the development of new crop cultivars is more. Recently, speed breeding (SB) has emerged as a successful technology that aims to shorten the breeding cycle and accelerate crop improvement through rapid generation advancement (RGA) achieved by creating growing conditions that promote rapid plant growth and hasten flowering in controlled environments. Speed breeding technology involves growing plant populations under environmental conditions that are conducive to early flowering to accelerate generation time.

Maintaining temperature and humidity conditions is crucial for successful SB. Light is a critical parameter for plant growth, where both intensity and quality are important. Increasing light intensity in SB facilities may increase photosynthetic rate and decrease days to flowering. However, at high light intensity, elevated CO₂ may be required to achieve additional increases in photosynthesis. Advances in lighting technology, along with automated growth systems from the horticulture industry, can be used to manipulate plant growth in large-scale and cost-effective SB platforms. Successful implementation of SB technology has significant potential to accelerate crop improvement, enhance genetic gain, and address global challenges in agriculture quickly. The accelerated breeding process enables the introduction of beneficial traits, such as increased yield, improved nutritional content, disease resistance, tolerance to specific stresses, and other agronomically important characteristics at a faster rate.

Keywords: Speed breeding, Environment, Quality, Intensity

Male Gametophytes Constraints through Pollen Cryopreservation in Vegetables S A Genetic Security Approach

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Pollen cryopreservation is a critical biotechnological approach for long-term conservation and utilization of male gametophytes in vegetable crops, ensuring genetic security and supporting hybrid breeding under constraints of asynchronous flowering and limited pollen viability. The methodology involves ultra-low temperature storage, typically in liquid nitrogen (-196°C), where cellular metabolism and enzymatic activities are completely arrested, thereby stabilizing pollen physiology. Successful cryopreservation requires optimization of multiple parameters, including pollen collection at the optimal developmental stage (tricellular or bicellular phase), desiccation kinetics, cryoprotectant formulations, cooling and warming regimes, and post-thaw viability assays.

Pre-treatment strategies are pivotal, as uncontrolled ice crystal formation during freezing causes membrane rupture and loss of cytoplasmic integrity. Controlled desiccation (to 5–15% relative moisture content) using silica gel or vacuum drying has been effective in cucurbits and solanaceous vegetables, while encapsulation-dehydration in calcium alginate beads enhances structural protection. Cryoprotectants such as sucrose, trehalose, DMSO, and glycerol are widely used to stabilize membranes and proteins by replacing water molecules and reducing intracellular ice nucleation. Vitrification techniques, which transform cytoplasm into a glassy state, have further improved pollen survival in species like tomato (*Solanum lycopersicum*) and chilli (*Capsicum annuum*). Post-thaw recovery involves rehydration and in vitro germination assays to evaluate pollen tube emergence, metabolic activity (e.g., TTC reduction, FDA fluorescence), and fertilization competence. Applications of pollen cryopreservation in vegetable crops are extensive, ranging from hybrid seed production and temporal synchronization of gametes to germplasm exchange across geographic and seasonal barriers. It plays a crucial role in safeguarding male gametes against biotic and abiotic stresses driven by climate change.

Keywords: Pollen cryopreservation, vegetable crops, liquid nitrogen, germplasm conservation, climate resilience

Genetic Evaluation of Bottle Gourd (*Lagenaria siceraria* L.) for Summer Cultivation under Southern Telangana Conditions: Towards Adaptation and Mitigation of Climate Change Impacts

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The present investigation was conducted over three consecutive summer seasons (2021–22, 2022–23 and 2023–24) at Vegetable Research Station, Rajendranagar, SKLTGHU, to evaluate the performance of bottle gourd genotypes under rising summer stress conditions. The experiment was laid out in a Randomized Block Design (RBD) with 10 genotypes: DBOGV-225, VRBOG-63-02 (Kashi Kirti), RHRBG-35, BBOG-2-21, BBOG-3-1 (C), Punjab Barkat (C), Arka Shreyas, RHRBG-54, NDBG-28, and VRBOG-16, and was replicated three times. In the context of increasing temperatures, erratic rainfall and soil moisture deficits due to climate change, the study aimed to identify high-performing genotypes that exhibit resilience and stable productivity under heat-prone conditions.

Among the tested genotypes, RHRBG-35 demonstrated stable morphological performance under summer stress, recording the maximum fruit length (39.79 cm) across all three seasons. Punjab Barkat (C) exhibited the highest average fruit weight (1200.00 g) and overall yield (367.03 q/ha), followed by RHRBG-54, which recorded an average fruit weight of 1113.33 g and an overall yield of 326.93 q/ha under Telangana Condition. These genotypes showed consistent performance in terms of fruit size and yield, making them particularly valuable for climate-resilient varietal development and cultivation in Telangana. The findings underscore the importance of selecting and promoting climate-resilient bottle gourd genotypes that can maintain stable yields under summer stress, thereby contributing to sustainable crop production in a changing climate.

Keywords: Climate change, Bottle gourd, Genotypes, Mitigation Strategies and Yield

Building Climate-Resilient Dryland Horticulture by Integrating Soil and Water Conservation Strategies in Wanaparthy District of Telangana

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Dryland horticulture has emerged as a strategic pathway for ensuring livelihoods, nutritional security, and ecological resilience in semi-arid India. The increasing variability of climate—manifested through erratic monsoons, recurrent droughts, rising temperatures, and high-intensity rainfall—poses a serious challenge to the sustainability of rainfed horticulture. Wanaparthy district of Telangana, with its semi-arid climate, shallow red sandy loam soils, and high dependence on rainfed farming, represents both the vulnerabilities and opportunities of such landscapes. This paper highlights the need for integration of soil and water conservation (SWC) measures, with climate-resilient dryland horticultural practices, to act as robust adaptation and mitigation strategies. Different SWC measures including Continuous Contour Trenches, Staggered Contour Trenches, Water Absorption Trenches, contour and field bunding, trench-cum-bund structures, stone bunding, farm ponds, mini percolation tanks, gully plugs, and gabion structures in enhancing rainwater harvesting, soil moisture conservation and improving soil fertility for building resilience along with increasing production and productivity of dryland horticulture crops, in view of heightened threats of climate change. Their (SWC measures) integration with orchard establishment, drip and pitcher irrigation, mulching, tank silt application, and crop diversification would significantly improve soil moisture retention, water-use efficiency, crop yields, and farmer incomes. The paper also advocates for effective convergence of schemes for not only strengthening local adaptation but also creating a replicable model of climate-resilient dryland horticulture for adoption in other semi-arid regions of India.

Mitigation Strategies for Climate Change through Integrated Nutrient Management in Potato (*Solanum tuberosum* L.) Cultivation

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The present investigation was carried out over two consecutive *Rabi* seasons during 2021–22 and 2022–23 at Sri Konda Laxman Telangana Horticultural University, Mulugu, Siddipet district, Telangana in a Randomized Block Design (RBD) with 13 treatments and replicated thrice. Against the backdrop of increasing climate variability and its adverse impact on soil health and crop productivity, the study aimed to evaluate the effectiveness of integrated bioavailable and inorganic nutrient sources as a climate change mitigation strategy in potato cultivation. The results revealed that integrated nutrient treatments significantly enhanced soil enzymatic activity and nutrient availability as key indicators of soil resilience under climatic stress. Dehydrogenase activity a marker of microbial activity and biological health was observed highest ($0.558 \mu\text{g TPF g}^{-1} \text{ soil hr}^{-1}$) in 100 % Recommended dose of NPK @ 120:240:120 kg NPK/ha at 30 DAP, at 60 DAP it was maximum ($0.719 \mu\text{g TPF g}^{-1} \text{ soil hr}^{-1}$) in 75 % Recommended dose of NPK + Organic NPK and after harvest ($2.254 \mu\text{g TPF g}^{-1} \text{ soil hr}^{-1}$) in 50 % Recommended dose of NPK + Organic potash respectively.

It was recorded Alkaline phosphatase activity is essential for phosphorus mobilization especially under moisture and temperature-stressed conditions, recorded the highest values at 30 DAP ($0.156 \mu\text{g pNP g}^{-1} \text{ soil hr}^{-1}$) in 75 % Recommended dose of NPK + Organic NPK with micronutrients, at 60 DAP ($0.177 \mu\text{g pNP g}^{-1} \text{ soil hr}^{-1}$) in 50 % Recommended dose of NPK + Organic potash and after harvest ($0.144 \mu\text{g pNP g}^{-1} \text{ soil hr}^{-1}$) in 50 % Recommended dose of NPK + Organic NPK. Urease activity closely linked to nitrogen mineralization and more sensitive to environmental fluctuations, was not significantly affected at 30 DAP. However, it was significantly higher at 60 DAP ($0.567 \mu\text{g NH}_4\text{-N g}^{-1} \text{ soil hr}^{-1}$) in 50 % Recommended dose of NPK + Organic potash and after harvest ($0.145 \mu\text{g NH}_4\text{-N g}^{-1} \text{ soil hr}^{-1}$) in 75 % Recommended dose of NPK + Organic NPK Integrated nutrient approaches can stabilize nitrogen dynamics under variable climatic conditions. These findings underscore the role of integrated nutrient management (INM) as a viable mitigation strategy to counteract the negative impacts of climate change on potato production. By enhancing bioavailability of nutrients, supporting enzymatic function and improving soil fertility, INM offers a sustainable pathway to increase resilience in potato-based agro-ecosystems under future climatic uncertainty.

Keywords: Climate change, Potato, Urease, Dehydrogenase, Alkaline phosphatase and Integrated Nutrient Management

Studies on The Effect of First-Generation Seed Tuberlets Produced from True Potato Seed (TPS) on Growth and Yield of Potato Under Southern Telangana Agro Climatic Conditions

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An experiment was conducted during the 2022–23 *Rabi* season at the PG Research Block, College of Horticulture, Rajendranagar, Hyderabad, to evaluate the growth performance of first-generation seed tuberlets developed from True Potato Seed (TPS) under the agro-climatic conditions of Southern Telangana. The study employed a Factorial Randomized Block Design (FRBD) with two factors: three TPS hybrids— V_1 (PRT-17A $\times$ D-150), V_2 (PSL/76-6 $\times$ D-150), and V_3 (KP-15C3 $\times$ D-150)—and three tuber size categories—large (S_1 : 64–226 g), medium (S_2 : 50–63 g), and small (S_3 : 22–49 g), with three replications. Among the treatments, V_1S_1 (PRT-17A $\times$ D-150 with large-sized tubers) significantly outperformed others in all growth parameters, including maximum plant height (40.18 cm at 30 DAP and 61.10 cm at 60 DAP), highest number of main stems (12.83), compound leaves (11.34 at 30 DAP and 16.32 at 60 DAP), and chlorophyll content (41.33 SPAD at 30 DAP and 54.92 SPAD at 60 DAP). These results underline the potential of TPS-derived large-sized tuberlets, especially from the PRT-17A $\times$ D-150 hybrid, as a climate-resilient adaptation strategy for potato cultivation in the region. The use of TPS reduces the dependency on conventional seed tubers, which are often costly and vulnerable to disease and supply-chain disruptions. Furthermore, selecting optimal tuber size ensures better resource-use efficiency, improved plant vigor, and enhanced yield potential, contributing to sustainable intensification of potato production. Such approaches align with climate change mitigation goals by enhancing productivity while optimizing input use and reducing the carbon footprint of seed potato logistics.

Keywords: Potato, propagation, true potato seed, growth, yield

Mitigating Climate Change Impacts on Cut Flowers: Effect of Biocides on Postharvest Vase Life of Gypsophila

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Climate change poses significant threats to the cut flower industry, with rising temperatures and altered precipitation patterns creating ideal conditions for microbial growth and proliferation. A major cause of deterioration in cut flowers is blockage of xylem vessels by microorganisms that accumulate in the vase solution or in the vessels themselves, exacerbating the impacts of climate change. To combat this issue, floral preservatives have been developed, typically including biocides to inhibit bacterial proliferation. In the context of climate change, the role of bactericides becomes even more critical. By controlling harmful bacteria, bactericides help prevent bacterial embolism, ensuring that cut flowers can maintain optimal water uptake and freshness. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events can reduce vase life, increase flower senescence, and disrupt supply chains. This study investigates the efficacy of biocides in mitigating climate change impacts on cut flowers. Fourteen biocide treatments were evaluated for their effect on postharvest vase life of cut flowers. Results showed that biocide treatment significantly improved water uptake, reduced transpiration loss, and extended vase life. The most effective treatment, combining 2 % sucrose and 8-HQS (200 ppm), extended vase life was 15.5 days. This study demonstrates the potential of biocides in enhancing climate resilience of cut flowers, providing a valuable strategy for the floriculture industry to adapt to climate change. 8-HQS, a germicide widely used in the floral industry, acts as an antimicrobial agent, effectively reducing microbial growth and promoting increased water uptake. This is particularly important in the face of climate change, where drought and heat stress can further compromise cut flower quality. By incorporating 8-HQS and other bactericides into floral preservatives, the industry can better adapt to the challenges posed by climate change.

Keywords: Climate change, Biocides, Bactericides, 8-HQS, Microbial growth, Vase life

Adaptation and Mitigation Strategies for Coconut to Climate Change

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Plantation crops mainly coconut, rubber, tea, coffee, oil palm, arecanut, cashew, cocoa grown in ecologically sensitive areas like coastal belts and hilly areas are under the threat of climate change. Among, plantation crops, coconut (*Cocos nucifera* L.), in the tropics is highly vulnerable to climate change due to its perennial nature and long life cycle. Rising temperatures, irregular rainfall, droughts, cyclones and pest outbreaks pose significant threats to coconut productivity and farmer livelihoods. Adaptation strategies include the development and dissemination of climate-resilient varieties tolerant to drought, salinity and diseases, adoption of efficient water management practices such as drip irrigation, mulching and rainwater harvesting, integrated nutrient and pest management and diversification of coconut-based farming systems to ensure income security. Mitigation strategies focus on enhancing carbon sequestration through coconut-based agroforestry, recycling of biomass and organic residues, use of biofertilizers and reducing greenhouse gas emissions by promoting organic and sustainable farming practices. Strengthening early warning systems, capacity building and policy support are also crucial for building resilience. Together, adaptation and mitigation strategies not only safeguard coconut production but also contribute to sustainable livelihoods and climate resilience in coconut-growing regions.

Keywords: Adaptation, Mitigation, Coconut and Climate change

Climate-Smart Role of Plant Growth Regulators in Enhancing Physiological Efficiency and Quality of Potted Syngonium

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The experiment “Climate-Smart Role of Plant Growth Regulators in Enhancing Physiological Efficiency and Quality of Potted Syngonium” was conducted under 50% shade net during 2023–24 and 2024–25 at the College of Horticulture, Rajendranagar, SKLTGHU. In the context of climate variability and increasing stress conditions that affect the growth and aesthetic quality of ornamentals, the study was attempted to assess plant growth regulators (PGRs) as a climate-resilient horticultural strategy. The experiment was laid out in a completely randomized design with three replications. Treatments included T₁: Benzyladenine 150 ppm, T₂: Benzyladenine 250 ppm, T₃: Salicylic acid 100 ppm, T₄: Salicylic acid 200 ppm, T₅: Gibberellic acid (GA₃) 150 ppm, T₆: Gibberellic acid (GA₃) 250 ppm, T₇: Ascorbic acid 100 ppm, T₈: Ascorbic acid 200 ppm, and T₉: Water spray (control). Results over two years (2023–24, 2024–25) and pooled analysis indicated that Salicylic acid 200 ppm (T₄) significantly enhanced adaptive physiological traits such as maximum leaf area index (2.28), higher specific leaf weight (0.005 g/cm²), and reduced specific leaf area (192.91 cm²/g), suggesting improved photosynthetic efficiency and stress resilience. For quality attributes, Salicylic acid 200 ppm also recorded the highest visual plant grade (4.77) and colour grade (4.53), reflecting superior ornamental value. Meanwhile, Benzyladenine 150 ppm (T₁) was most effective in enhancing chlorophyll content (42.98), which is critical for sustaining plant vitality under sub-optimal growing conditions.

Keywords: Salicylic acid, Benzyladenine, Gibberellic acid, Climate smart

Cultivating Resilience: Climate-Smart Strategies for Sustainable Horticulture

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Climate change and growing climatic variability are exerting profound pressures on horticultural crops, disrupting pollination dynamics, shifting crop growth cycles, and amplifying water scarcity. To secure productivity and long-term sustainability, the focus must move beyond documenting impacts toward adopting evidence-driven strategies that convert vulnerabilities into opportunities. Horticulture faces distinct risks such as recurrent heatwaves, irregular rainfall, mismatched phenological stages, and ecosystem decline, with tropical and subtropical zones being particularly exposed. In India, where horticulture contributes nearly 30% of agricultural value from just 6% of cropped land, the sector reflects both immense potential and acute vulnerability. Promising interventions include protected cultivation structures that enhance efficiency while reducing water demand, precision irrigation methods that raise yields, and climate-resilient cultivars developed through modern breeding tools.

Agroforestry intercropping offers substantial carbon sequestration (0.25–76.5 Mg C/ha/year), while renewable energy solutions like solar irrigation and organic mulching mitigate emissions. These practices also generate co-benefits such as improved productivity, resource-use efficiency, and biodiversity conservation. Scalable resilience measures—such as watershed-based water harvesting, pollinator-friendly landscapes, and mobile agrometeorological advisories have shown adaptability across varied agro-climatic contexts. Effective implementation, however, requires enabling policies (MIDH, NMSA, NICRA), multi-stakeholder collaboration, and stronger extension services. Integrating technological innovations with institutional support and community participation will be key to building climate-smart horticulture that sustains food security, secures farmer livelihoods, and protects ecosystem health.

Keywords: Climate-smart horticulture, Protected cultivation, sustainable horticulture, Carbon sequestration, Climate resilience

Horticulture in Carbon Sequestration and Climate Change Mitigation

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Climate change is a critical global challenge, with the agriculture sector being both a contributor to greenhouse gas (GHG) emissions and a potential solution through mitigation strategies. Horticulture, encompassing the cultivation of fruits, vegetables, ornamental plants, and medicinal crops, plays a crucial but often underemphasized role in climate change mitigation particularly through carbon sequestration. Sustainable horticultural practices can significantly enhance soil organic carbon storage and reduce emissions from inputs and operations. Key strategies include the application of organic amendments such as compost and biochar, the adoption of conservation tillage, the integration of cover crops, and the use of perennial species and agroforestry systems. These practices not only sequester atmospheric carbon dioxide (CO₂) into soil and plant biomass but also improve soil health, fertility, and water-holding capacity, contributing to increased resilience against climate stressors.

Additionally, innovations in controlled environment agriculture such as greenhouses, vertical farming, and precision horticulture reduce resource use and enable low-emission food production, particularly when powered by renewable energy. Urban and peri-urban horticulture further contribute to mitigation by lowering emissions from food transport and reducing heat island effects through greening. While individual horticultural systems may have smaller footprints compared to large-scale agriculture, their high productivity, diversification potential, and cumulative benefits make them powerful tools for climate action. To realize this potential, integrated policies, targeted investments, capacity building, and research are essential to scale up climate-smart horticultural practices. Thus, horticulture offers a dual opportunity to mitigate climate change while advancing food security, ecological balance, and sustainable livelihoods.

Keywords: Climate change mitigation, Carbon sequestration, Urban Horticulture

Plastic Mulching as a Climate-Smart Strategy for Sustainable Turmeric Production

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Mulching plays a pivotal role in enhancing the climate resilience of turmeric (*Curcuma longa* L.), a crop highly sensitive to soil moisture fluctuations, temperature extremes, and weed competition. Climate change has led to erratic rainfall patterns, prolonged dry spells, and rising temperatures, posing challenges to sustainable turmeric production. Mulching using plastic films acts as a protective layer that conserves soil moisture, moderates temperature, and reduces erosion, thereby buffering the crop against climatic variability. Plastic mulches provide immediate benefits in water-use efficiency and weed suppression. Moreover, mulching reduces the risk of yield loss from prolonged dry periods and maintains stable rhizome quality under fluctuating climates.

The experiment has been taken up at Turmeric Research Station, Kammarpally for the four consecutive years from 2019-20 to 2022-23 to assess the effect of different plastic mulches on growth and yield of turmeric under different plastic mulch conditions. Turmeric crop is severely invaded with weeds during initial stages. Prolonged weed free period is needed for good crop stand and better plant growth. Labour availability during critical weed control stages of crop triggers the pressure on weed management. Plastic mulching is one of the best alternates to control the weeds and improve the water use efficiency. In this trial, different plastic mulches black plastic mulch 25 microns and 30 microns, gray plastic mulch with 25 microns and 30 microns have been taken as plastic mulching material and without any plastic mulching was taken as control. The experimentation was done in a randomized block design and replicated four times. The results enunciated that the plants with black plastic mulch with 30 microns thickness recorded maximum mean fresh rhizome yield (42.99 t/ha) followed by black plastic mulch with 25 microns thickness (37.03 t/ha) as compared to other mulches and control (Without mulching). Thus mulching is not only an agronomic practice for productivity enhancement but also a climate-smart strategy that strengthens the adaptive capacity of turmeric cultivation in vulnerable agro-ecosystems.

Keywords: Turmeric, mulching, fresh rhizome yield, plant height, black plastic mulch

Response of South American Cocoa Genotypes to Water Deficit Stress Conditions

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Raising concerns about climate change and changing rainfall patterns necessitates screening for drought tolerance in cocoa genotypes in order to achieve long-term sustainability of production. The present study was conducted to evaluate the biochemical responses of 6 exotic cocoa genotypes along with released variety VTLCH3 under two water deficit conditions, i.e., 100% FC and 40% FC. The identification of highly resistant and highly sensitive genotypes was based initially on the standard score chart prepared based on morphological observations after stress imposition. The genotype, VTLCH3 which is tolerant to drought, identified was used as a check in the experiment. The physiological parameters, relative water content, chlorophyll stability index, membrane stability, and chlorophyll content were recorded high in tolerant and highly tolerant genotypes whereas these parameters were comparatively low in susceptible. Biochemical parameters such as proline, nitrate reductase, superoxide dismutase (SOD), and glycine betaine (GB) were estimated. The biochemical parameters, proline, superoxide dismutase (SOD) and glycine betaine (GB) content were increased under drought stress condition at 40% FC. However, nitrate reductase recorded a decline in its activity under drought stress in all the genotypes. Under stress condition, all biochemical indicators showed a positive and significant association with the percentage of leaves retained, showing that they play a key role in establishing drought tolerance mechanism among that, proline showed maximum correlation with the percentage of leaves retained. The results of the study concluded that, there is a role or involvement of these parameters in imparting drought tolerance to cocoa and these can be used as a promising biomarkers or indicators for identifying stress tolerance in cocoa.

Keywords: cocoa, biochemical parameters, water deficit stress, physiological parameters, field capacity

Cultivating Resilience: Soil Conservation and Climate Change Mitigation in Horticulture"

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Horticulture production depends on soil health, which is an essential component in achieving climate resilience. Healthy soils ensure higher yields, better quality produce, and long-term sustainability through its physical, chemical, and biological properties. The sustainability of high-valued horticulture crops is under threat due to climate changes which resulted in irregular rainfall, prolonged dry spells, rising temperatures, and increased soil salts and acidity. These crops, sensitive to soil health and water availability, often face reduced yields, poor quality, and greater pest, disease outbreak under adverse climatic conditions. Climate change disrupts soil health in the production of horticulture crops by causing erosion, nutrient loss, moisture stress, salinization, and microbial imbalance. These impacts weaken soil fertility and structure at each stage of crop from sowing, germination, flowering, fruiting, and harvest. These effects resulted in reduced yields, poor quality in crop and long-term soil degradation.

Global temperatures have risen by 1.1°C due to human activity, intensifying extreme weather and threatening ecosystems, health, and food security worldwide (IPCC, 2023). Caring for Soils to measure, monitor and manage provides a structured framework to safeguard soils in horticultural systems. Measuring the soils through soil testing, carbon stock assessment, and soil moisture analysis establishes baselines for fertility and resilience. Monitoring of soils using microbial indicators, digital tools, and climate soil interaction models ensure early detection of degradation and supports adaptive decision-making. Management practices focus on regeneration through organic matter incorporation, conservation tillage, precision irrigation, integrated nutrient management, and agroforestry. A crucial component of soil conservation is the role of beneficial microorganisms. Microbes such as arbuscular mycorrhizal fungi, nitrogen-fixing bacteria, and plant growth-promoting rhizobacteria enhance nutrient availability, improve soil structure, and increase crop tolerance to drought and salinity. By fostering soil microbial diversity through compost application, biofertilizers, and reduced chemical inputs, horticultural systems can improve soil carbon sequestration and ecosystem services. Healthy soils act as carbon sinks and buffers against climate extremes, reducing greenhouse gas emissions while sustaining horticulture productivity. This holistic approach strengthens the long-term sustainability of horticultural production while positioning soils as a frontline defense in climate change mitigation and adaptation.

Keywords: Soil health, climate resilience, horticulture, carbon sequestration, microbial indicators

Review on Plant Breeding Techniques in the Development of Climate-Resilient Varieties in Vegetable Crops

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The increasing frequency of climate-induced stresses need to be addressed. Plant breeding has emerged as a cornerstone in developing climate-resilient vegetable varieties. Advanced techniques such as marker-assisted selection (MAS), genomic selection, and CRISPR-Cas9 gene editing have accelerated the development of resilient cultivars. For example, MAS has enabled the breeding of salt-tolerant tomato lines, while CRISPR has been used to enhance disease resistance in cabbage. Several vegetable crops have been successfully bred for climate resilience using both traditional and modern plant breeding techniques.

For instance, drought-tolerant tomato varieties such 'Roma VF' has been developed to perform well under limited water conditions. Heat-resistant spinach cultivars like 'Bloomsdale Long Standing' maintain leaf quality even in high temperatures. Salt-tolerant okra varieties, such as 'Kashi Kranti', show improved growth in saline soils. In cabbage, breeding for resistance to black rot and heat stress has led to cultivars like 'Pusa Drumhead'. Amaranth, a leafy vegetable, naturally exhibits strong tolerance to heat and drought, making it ideal for arid regions. These examples highlight how targeted breeding efforts can enhance the adaptability of vegetable crops to climate stress, ensuring food and nutritional security in vulnerable environments. These innovations not only improve crop performance under stress conditions but also contribute to sustainable agriculture by reducing dependency on chemical inputs and irrigation. The integration of breeding strategies with climate-smart agronomic practices is essential for building a robust vegetable production system that can thrive in a changing climate.

Keywords: Plant breeding techniques, Climate resilience, Vegetable crops

Review on Recent Advances in Role of Crispr-Cas9 on Development of Climate Proof Vegetable Varieties'

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CRISPR-Cas9 has revolutionized the development of climate-proof vegetable varieties by enabling precise, efficient, and targeted genome editing to enhance stress tolerance traits. This powerful tool allows scientists to modify or silence specific genes responsible for susceptibility to abiotic stresses such as drought, heat, salinity, and cold conditions increasingly intensified by climate change. For example, CRISPR has been used to edit genes in tomato to improve drought tolerance and delay fruit softening, while in cabbage and brinjal, it has helped enhance resistance to heat stress and bacterial wilt. Unlike traditional breeding, which can be time-consuming and imprecise, CRISPR-Cas9 accelerates the breeding cycle and introduces desirable traits without affecting the crop's nutritional value or yield potential.

Unlike conventional breeding, CRISPR allows targeted modification of stress-responsive genes without introducing foreign DNA, making it faster and more accurate. For example, in **tomato**, CRISPR has been used to knock out the SIMAPK3 gene, improving drought tolerance and fruit firmness. In cabbage, editing the BrERF gene has enhanced heat stress resilience, while in cucumber; CRISPR has been applied to improve salinity tolerance by modifying ion transport pathways. Similarly, eggplant has seen improvements in resistance to bacterial wilt through targeted gene disruption. These advancements not only boost crop performance under adverse climatic conditions but also support sustainable agriculture by reducing dependence on irrigation and chemical inputs. Its application in vegetable crops offers a sustainable pathway to secure food production in vulnerable agro-climatic zones, making agriculture more resilient to future environmental challenges.

Keywords: CRISPR – CAS9, Climate proof varieties, Vegetable Crops

Effect of Climate Change on Seed Production of Vegetable Crops in India: A Review¹

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Climate change has significantly impacted seed production of vegetable crops in India, disrupting both quantity and quality due to rising temperatures, erratic rainfall, and increased incidence of pests and diseases. These climatic shifts affect flowering synchrony, pollination success, and seed maturation, leading to reduced seed viability and germination rates. Climate change had a profound impact on seed quality and seed yield of vegetable crops in India, disrupting key physiological and reproductive processes. Elevated temperatures often accelerate seed development, leading to premature maturation and reduced seed viability, as observed in crops like tomato, brinjal, and cucumber. Erratic rainfall and prolonged droughts affect soil moisture levels, which are critical for proper seed formation and maturation, resulting in poor seed set and lower germination rates. Additionally, increased humidity and temperature fluctuations have heightened the incidence of fungal and bacterial infections, compromising seed health and storage longevity.

Studies have shown that elevated CO₂ levels may enhance vegetative growth but alter the biochemical composition of seeds, affecting their nutritional value and vigor. These changes not only reduce the efficiency of seed production systems but also pose economic challenges for farmers and seed producers, especially in regions dependent on open-field cultivation. Economically, this decline in seed productivity affects smallholder farmers who rely on seed multiplication for income and local supply chains. Seed production firms face higher production costs due to increased need for controlled environments and disease management, which in turn raises seed prices for growers. The cumulative effect threatens India's vegetable sector, which contributes significantly to both domestic food security and agricultural GDP. Adaptive strategies such as climate-resilient breeding, protected cultivation, and decentralized seed systems are becoming essential to sustain seed production under changing climatic conditions. Addressing these issues requires climate-adaptive breeding, improved seed processing technologies, and region-specific cultivation strategies to ensure sustainable vegetable seed production in India.

Keywords: Seed Production, Climate change, Vegetable Crops

Phytoremediation Efficiency of Flower Crops in Heavy Metal Containing Media

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Soil and water contamination caused by rapid urbanization, industrialization, and population growth has become a major environmental concern. Phytoremediation, an eco-friendly method that utilizes plants to remediate polluted soils, offers a sustainable solution. Food crops are not-suitable for cultivation due to the accumulation of heavy metals in edible parts, making ornamental crops a safer alternative. In this present study, Marigold (*Tagetes erecta*), Chrysanthemum (*Chrysanthemum indicum*), and gaillardia (*Gaillardia pulchella*) were assessed for their phytoremediation potential in lead (Pb) and cadmium (Cd)-treated soils. The results revealed that Gaillardia exhibited the maximum uptake (1.66 µg/pot Pb and 0.61 µg/pot Cd), followed by chrysanthemum, while Marigold showed the lowest accumulation. Notably, growth and yield parameters of these ornamentals are not adversely affected. Therefore, gaillardia and chrysanthemum can be recommended as effective ornamental crops for phytoremediation of heavy metal-contaminated soils and generate income even in heavy metal contaminated soils.

Keywords: Phytoremediation, Heavy metals, Lead, Cadmium, Marigold, Gaillardia, Chrysanthemum

Metabolic Profiling of Turkey Berry (*Solanum Torvum* Sw.) Rootstock Mediated Root Knot Nematode (*Meloidogyne Incognita* Kofoid and White) Resistance on Grafted Tomato (*Solanum Lycopersicum* L.)

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Climate change and environmental variability significantly alter the interactions between plants and soil-borne pathogens, particularly root-knot nematodes (*Meloidogyne* spp.), which are among the most destructive pests in solanaceous vegetables. Rising temperatures, irregular rainfall and soil moisture fluctuations accelerate nematode reproduction and virulence, intensifying crop losses in tomato and related crops. To mitigate nematode-induced damage and promote climate-resilient horticulture, an experiment was conducted during 2024–25 at the Automated Polyhouse of ICAR-NBPGR, Regional Station, Rajendranagar, Hyderabad, and SKLTGHU, Mulugu, Siddipet District. The study evaluated the nematode resistance of tomato (Kashi Amrut) grafted on turkey berry (*Solanum torvum* Sw.), compared with non-grafted controls. Results revealed that non-grafted *S. torvum* under un-inoculated nematode conditions exhibited the highest resistance, coupled with superior growth traits. Importantly, grafting enhanced the resilience of tomato under nematode-infested conditions, demonstrating improved physiological and biochemical responses. Enzymatic activity assays indicated elevated levels of catalase, peroxidase, polyphenol oxidase and phenylalanine ammonia-lyase in resistant rootstocks, suggesting an enhanced defence response. In addition, metabolic profiling detected untargeted compounds potentially involved in direct nematode suppression and resistance pathways. These findings highlight the dual role of enzymatic defence and metabolite accumulation in conferring resistance under nematode stress. The study further emphasizes that climate-smart nursery interventions, such as resistant rootstock grafting and controlled environment seedling production, can buffer the adverse effects of climate change on plant-nematode dynamics. By combining host resistance with adaptive management strategies, it is possible to enhance crop productivity while reducing chemical nematicide dependency. Overall, the integration of climate resilience, biological resistance and sustainable nursery practices can strengthen solanaceous vegetable production systems against nematode pressure under changing climatic scenarios.

Keywords: Climate change, Tomato, *Solanum torvum*, catalase, peroxidase, polyphenol oxidase, phenylalanine ammonia-lyase, Root knot nematode

Climate Change, Land Degradation, and Soil Health in Telangana: Shifting Trends and Adaptation over Two Decades

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Over the past two decades, Telangana has witnessed profound climate shifts marked by rising temperatures, erratic rainfall, and intensifying extreme events. Average temperatures across the state have risen steadily, with Hyderabad recording a 0.07 °C increase alongside declining rainfall (–22.1%) and humidity (–6.7%). Heat waves are becoming harsher, peaking at 48.9 °C in Nalgonda (2015), while winters are warming with fewer cold-wave days, altering seasonal dynamics. Rainfall patterns show high variability. The state’s wettest years were 2020–22, exceeding long-term averages by 30–53%, while 2023–24 remained slightly above normal. However, regional disparities persist: southern districts show rainfall gains, whereas northern and eastern districts face declines up to 157 mm. Telangana is also recording more extreme events—517.5 mm fell in Wazeedu (2013) in a single day, while October 2023 was the driest in six decades. Climate change, combined with intensive agriculture, is accelerating land degradation. About 57% of Telangana’s area faces moderate to severe soil erosion, with districts like Adilabad, Karimnagar, and Warangal showing acute risks. Soil studies reveal widespread nitrogen deficiency and localized imbalances in phosphorus and potassium, with variability across districts and cropping systems. Adaptation responses include large-scale afforestation (Haritha Haram), agroforestry, soil conservation, and land degradation neutrality planning. These strategies enhance resilience, restore soil fertility, and sustain agriculture in the face of climate stress. Long-term monitoring, sustainable land management, and farmer-focused climate services remain critical to safeguarding Telangana’s food, water, and ecosystem security.

Keywords: Rising Temperatures, Erratic Rainfall, Extreme Weather Events, Land Degradation, Adaptation Strategies

Horticultural Industrial Byproducts: Impact on Climate and Mitigation Strategies

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Horticultural industries generate a substantial amount of byproducts, including organic waste (plant residues, stems, fruit peels), packaging materials, and processing waste. When these byproducts are not properly managed, they can lead to significant environmental impacts, including soil pollution, water contamination, greenhouse gas emissions, and loss of biodiversity. Improper disposal, particularly through landfill or open burning, exacerbates these environmental challenges, contributing to the accumulation of plastic waste and the release of harmful pollutants. To mitigate these negative effects, several strategies have been proposed, including composting, vermiculture, anaerobic digestion, and biogas production. These methods allow organic waste to be converted into valuable resources, such as nutrient-rich compost, while also reducing methane emissions from landfill decomposition.

Additionally, byproduct valorization - the process of turning waste into value-added products like biofuels, bioplastics, or organic fertilizers - can help close the loop in agricultural production and reduce reliance on synthetic materials. The integration of circular economy principles, such as recycling, upcycling of packaging materials, and the adoption of biodegradable alternatives, further reduces waste and supports sustainable practices. Research into biodegradable packaging and waste-to-value technologies, such as converting plant waste into bioplastics or other marketable products, holds significant promise for enhancing sustainability in the horticultural sector. Finally, government incentivization, stricter regulations, and increased industry awareness are crucial to promoting responsible waste management practices. By adopting these mitigation strategies, the horticultural industry can not only reduce its environmental impact but also foster a more sustainable, circular economy that conserves resources and minimizes waste.

Keywords: Industrial Byproducts, Environmental Impact, Mitigation Strategies

Role of Horticultural Extension in Vulnerability Adaptation and Mitigation Strategies

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Horticultural extension services are vital in helping smallholder farmers address production challenges and adapt to the growing threat of climate change. Despite their importance, limited attention has been given to strengthening the capacity of extension agents to support farmers in managing climate risks effectively. Climate change threatens smallholder food production, making adaptation and mitigation strategies essential in horticulture. Adaptation strategies focus on building resilience while sustaining productivity. Crop diversification spreads risks and enables the use of drought, heat and disease resistant varieties. Precision technology tools such as GPS-guided machinery and sensor technology help optimize resources and reduce waste. Efficient irrigation systems, rainwater harvesting, and water-saving methods mitigate water scarcity, while protective structures like greenhouses safeguard crops against extreme weather and pests. Breeding and adopting climate-resilient crop varieties further enhance tolerance to stresses. Integrating agroforestry improves biodiversity, reduces erosion, and provides shade, supporting crops under variable climates.

Mitigation strategies aim at reducing greenhouse gas emissions and environmental impacts. Precision fertilizer application and organic nutrient use reduce nitrous oxide emissions and runoff. Conservation practices such as reduced or no-tillage improve soil carbon sequestration and structure. Transitioning to organic farming lowers dependence on synthetic inputs, while renewable energy adoption reduces carbon footprints in horticultural operations. Minimizing food waste across the supply chain helps curb methane emissions, and eco-friendly packaging further contributes to sustainability. Integrated Pest Management (IPM) reduces reliance on chemical pesticides, conserving natural ecosystems. Extension agents serve as educators, facilitators, and technology promoters, combining adaptation and mitigation practices to build resilience. By transferring knowledge, promoting sustainable innovations, optimizing resource use, and linking farmers with policies and markets, they play a pivotal role in ensuring food security, environmental conservation, and long-term sustainability in horticulture.

Keywords: Precision Technology, Mitigation Strategies, Integrated Pest Management, Organic Farming, Agroforestry

Black Soldier Fly Bioconversion: A Circular Bio-Economy Approach to Climate-Resilient agriculture

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Climate change poses significant threats to agriculture through declining soil fertility, extreme weather events, and increasing greenhouse gas (GHG) emissions from conventional farming and waste mismanagement. Sustainable, circular solutions are urgently required to build resilience in farming systems. The Black Soldier Fly (*Hermetia illucens*) offers a novel bioconversion pathway to transform agricultural residues, food waste, and organic by-products into high-value outputs while reducing environmental burdens. BSF larvae rapidly decompose organic substrates, reducing composting time by more than half compared to conventional processes, thereby lowering methane and nitrous oxide emissions from unmanaged biomass. The resultant residue (frass) is rich in organic matter and beneficial microbes, enhancing soil health, water-holding capacity, and nutrient cycling — critical attributes for climate-resilient farming. Simultaneously, BSF larvae provide a sustainable protein source for livestock and aquaculture, reducing dependence on soybean and fishmeal, both of which have high carbon and ecological footprints. Integrating BSF technology within agricultural systems offers multiple co-benefits: Reduced GHG emissions from waste, Improved soil resilience under climatic stress, Low-resource feed protein production, and Diversification of farmer income streams. Together, these outcomes align with national and global goals of promoting climate-smart and resilient agriculture.

This paper explores the potential of BSF-based circular bio-economy models as a scalable strategy to mitigate climate risks, enhance resource efficiency, and support sustainable food systems.

Resilient Horticulture in Telangana: Strategies for Climate Mitigation

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Horticulture is a key driver of Telangana's agricultural economy, contributing nearly 30% of the State Agricultural Gross Value Output (GVO) and providing livelihood security to millions of small and marginal farmers. In 2023–24, horticultural crops were cultivated over 12.96 lakh acres, with a total production of 42.58 lakh MT, underscoring the sector's critical role in food, nutrition, and income security.

However, the sector is increasingly vulnerable to rainfall instability, extreme temperatures, and climate shocks, which directly affect crop performance, quality, and farmer incomes. Climate change, with increment of mean temperature, changing pattern of rainfall and expanding recurrence of outrageous climatic occasions like cyclone, dry spell and flood is affecting agriculture and horticulture crops globally. Mitigation strategies must emphasize replacement of traditional cultivars with heat- and drought-tolerant varieties, climate resilient varieties, promotion of crop diversification, alteration in farm operations, adoption of precision farming (drip, fertigation, mulching) at smallholder level, usage of biopesticides and biofertilizers, shifting toward regenerative horticulture practices that enhance soil fertility, improve water-use efficiency, reduce carbon emissions. Nevertheless, adopting advance technologies like GIS, Pest modeling, Mapping of pest and diseases using remote sensing enhances decision making and resource management sustainability in horticulture. Despite the availability of climate-smart solutions such as micro-irrigation, protected cultivation, heat/disease-tolerant cultivars, biopesticides and biofertilizers to sustain soil health and soil biodiversity and IPDM their uptake remains limited due to socio-economic barriers. Smallholders face high capital costs for drip irrigation and protected structures, limited access to institutional credit and crop insurance, weak cold chain infrastructure, and knowledge gaps in precision farming. Moreover, fragmented markets and weak collective bargaining reduce profitability, thereby discouraging investments in resilient technologies. Equally critical are integrated farming systems and crop diversification to stabilize yields.

To overcome socio economic challenges in adopting climate mitigation strategies, Institutional level innovations like strengthening FPOs, scaling up climate-indexed crop insurance, digital weather advisories, investment in climate-resilient infrastructure, targeted financial incentives, support programs and investment in cold chains and processing units will mitigate climate risks and enhance farmer incomes. In conclusion, while Telangana's horticulture shows resilience through steady acreage expansion and its strong contribution to the state economy, sustainability is constrained by socio-economic barriers. Addressing these constraints through integrated technological, ecological, and policy-driven mitigation strategies is essential to safeguard farmer livelihoods and ensure climate-smart growth of the sector.

Keywords: Climate variability, horticulture, Telangana, socio-economic constraints, mitigation, adaptation, climate-smart practices

Effect of Climate Change on Production of Underutilized Fruits

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Underutilized fruits are nutrient-rich crops with significant traditional, nutritional, and medicinal value that are not widely cultivated or traded commercially, such as Indian Gooseberry (Amla), Bael, Jamun, and Karonda. They are notable for their adaptability to harsh conditions, low water requirements, and ability to support food and economic security, especially in developing regions. Fruit crops like ber, karonda, lasora and khejri have the capacity to flourish in arid and semi-arid environments when grown rainfed or with supplemental irrigation using captured rainwater during the establishment and other crucial stages. Several fruit species, including aonla, custard apple, ber, and the tamarind are widely known for their drought tolerance and capacity to flourish in low soils and marginal lands. Apart from this Climate change negatively affects underutilized fruits by disrupting flowering, fruiting, and ripening; decreasing yields and nutritional quality; increasing vulnerability to pests and diseases; and causing physiological disorders like fruit cracking. To adapt underutilized fruits to climate change, strategies include breeding and selecting climate-resilient varieties, implementing sustainable agronomic practices like agroforestry and soil conservation, using efficient irrigation, and empowering local communities through knowledge exchange and genetic resource conservation.

Keywords: Underutilized fruits, Climate change, Adaptive measures, Mitigation strategies

Building Climate-Smart Horticulture: Vulnerability, Adaptation, and Mitigation Strategies

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Climate change poses a significant threat to worldwide horticulture production by accelerating temperature extremes, altering rainfall patterns, and increasing the frequency of droughts, floods, and insect outbreaks. Horticultural crops are especially subject to environmental variations, resulting in lower yields, deteriorated quality, and higher disease incidence. Sustainability necessitates integrated adaptation and mitigation methods that address immediate hazards while fostering long-term resilience. The goal of means of adaptation is to improve crop and farming system resilience to climatic stressors. The development of climate-resilient varieties, effective watering via drip and micro-sprinkler systems, soil moisture conservation through mulching, and the use of protective structures such as greenhouses and shade netting are all important approaches. Cropping system diversification, integrated pest control, and biofertilizer use all improve resilience, while digital tools like as weather forecasting and early warning systems help make timely decisions. Mitigation measures aimed at reducing horticulture's carbon footprint include effective fertilizer management, conservation tillage, renewable energy in protected agriculture, and carbon sequestration through agroforestry and cover crops. Improved cold-chain management and waste reduction boost food security while also reducing emissions. A comprehensive approach, supported by legislation and capacity building, has the potential to turn horticulture into a climate-smart, sustainable sector.

Keywords: Climate change, Mitigation, Climate- resilient, Sustainability

Studies on the Effect of Plant Densities and Staking on Yield and Quality of Certain Sweet Potato (*Ipomoea Batatas* (L.) Lam.) Varieties under Central Telangana Conditions

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Climate change has emerged as one of the most critical challenges to global food and nutritional security, exerting severe impacts on horticultural systems through rising temperatures, erratic rainfall and increasing pest and disease incidences. Root and tuber crops like sweet potato, known for their climate-resilient traits, hold potential to sustain production under such stress conditions. In this context, the present investigation was conducted during 2024–2025 at PGIHS, Mulugu, to explore climate-resilient production practices with the objective of identifying climate-smart agronomic practices for yield enhancement and quality improvement. The experiment, laid out in a Factorial Randomized Block Design with three varieties (Bhu Sona, Bhu Krishna, Samrat) and six spacing treatments, revealed significant variation in vegetative growth, yield and quality traits under different plant densities. Closer spacing (20 × 20 cm) coupled with staking resulted in maximum tuber yield (84 t/ha in Bhu Krishna) and higher economic returns, while wider spacing (60 × 20 cm) favored vegetative growth but reduced yield per hectare due to lower plant population. Quality parameters such as starch, anthocyanin and β-carotene contents also showed significant interactions among varieties and spacing. These findings offer valuable insights for climate change adaptation in horticulture. High-density planting with staking enhances land-use efficiency, soil moisture conservation and carbon sequestration through greater biomass production. Varieties like Bhu Krishna, demonstrating superior yield under closer spacing, can be integrated into climate-resilient cropping systems to withstand unpredictable weather patterns. From a mitigation perspective, combining optimized spacing with resource-efficient practices such as mulching, drip irrigation and organic amendments can reduce greenhouse gas emissions, improve soil carbon storage and promote sustainable intensification. Overall, the study highlights that strategic manipulation of plant density, variety selection and input management can serve as low-cost, eco-friendly measures to enhance productivity, nutritional quality and environmental sustainability of horticultural crops in the face of climate change.

Keywords: Climate change, Sweet potato, Varieties, Spacing, Bhu Krishna

Harnessing Fruit Orchards for Carbon Sequestration and Climate Resilience

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Carbon Sequestration is a process of atmosphere carbon dioxide absorption, storage and accumulate carbon in various parts of plant body, thereby reduction of carbon dioxide levels in atmosphere. Fruit crops play a major role in carbon sequestration. The fruit crops are perennial – involved in capture, storage and accumulation of carbon dioxide (CO₂) in their biomass and translocate to soil to produce organic carbon. Fruit based systems can sequester up to 2.11 tons of carbon per hectare per year. Generally, fruit trees not only serve as economical but also act as reservoir for carbon dioxide (CO₂). Carbon sequestration helps in soil carbon enhancement, long term carbon storage in fruit crops, canopy coverage and reduced soil erosion, overcome climate change effects. The amount of carbon dioxide (CO₂) absorbed by Mango is 22-35kg/year, Citrus is 10-60kg/year, Guava is 6-37kg/year and Jamun is 15-80kg/year. Integrating carbon sequestration with agroforestry, minimal tillage into fruit production system not only reduce greenhouse gas emission but also enhances yield, and fruit quality. Thus, carbon sequestration serve as both environmental and economical asset in advancing the sustainability of fruit production under climate change scenario.

Keywords: Carbon sequestration, Fruit trees, climate change

Climate Change Impacts on Horticultural Crops and Pollinators: Challenges and Adaptive Strategies

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Climate change represents one of the most pressing challenges to global horticultural production and its associated pollinators. Shifts in temperature regimes, altered precipitation patterns, increasing frequency of extreme climatic events, and elevated atmospheric CO₂ directly influence crop physiology, phenology, yield and quality. Horticultural crops particularly fruits, vegetables, spices, and ornamentals are highly climate-sensitive, and even small fluctuations can lead to significant reductions in productivity, postharvest quality, and alterations in geographical suitability for cultivation.

Equally concerning is the impact of climate variability on pollinators, which are essential for the reproductive success of many horticultural crops. Bees, butterflies, flies and other pollinators experience population stress due to rising temperatures, habitat degradation, and changing floral resource availability. Climate-induced mismatches between crop flowering periods and pollinator activity threaten pollination efficiency, resulting in poor fruit set and reduced yields. Decline in pollinator abundance and diversity not only disrupt ecosystem services but also undermine food and nutritional security.

The dual vulnerability of crops and their pollinators highlights the complexity of climate change impacts on horticultural systems. Addressing these challenges requires the integration of adaptive strategies such as the development of climate-resilient cultivars, modification of cultural practices, adoption of protected cultivation and the conservation of pollinator habitats. Promoting diversified agro-ecosystems, reducing pesticide pressure and implementing pollinator-friendly landscape management can further mitigate risks. Strengthening research on crop-pollinator interactions under changing climates is essential for sustaining horticultural productivity, farmer livelihoods, and ecosystem stability in the future.

Keywords: Climate change, Phenology, Crop-pollinator interactions, Climate-resilient cultivars, Agro-ecosystem diversification, Sustainable horticulture, Protected cultivation

Mitigating Climate Change Impacts in Fruit Crops through Rootstock-Based Approaches

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Climate change poses a significant threat to global fruit production, driven by rising temperatures, erratic rainfall, prolonged droughts, salinity intrusion, and soil degradation. Fruit crops are particularly vulnerable due to their sensitivity to biotic and abiotic stresses, often resulting in reduced flowering, fruit set, yield, and quality. In this context, rootstocks have emerged as a vital climate adaptation tool, modulating scion vigor, canopy structure, nutrient uptake, stress resilience, yield, and fruit quality, thereby acting as biological buffers in tropical and subtropical fruit systems. In India, rootstocks support fruit cultivation across nearly 7 million hectares, highlighting their widespread importance. Citrus rootstocks such as Rough lemon (*Citrus jambhiri*) and Rangpur lime (*C. limonia*) enhance tolerance to drought, salinity, and soil-borne stresses, while improving canopy performance and ensuring sustainable citrus production. In mango, the dwarfing rootstock Vellaikolamban reduces canopy volume by 39.1% in Alphonso, 24.9% in Ratna, and 26.5% in Kesar, supporting high-density planting. Its compact crown structure protects trees from wind stress and also contributes to carbon sequestration, strengthening climate resilience. In grapes, Dogridge (*Vitis champinii*) is widely used for its tolerance to drought and salinity, maintaining ionic balance and efficient water uptake. It shows strong compatibility with Thompson Seedless, sustaining productivity in semi-arid regions where climate change intensifies water scarcity. Better salt exclusion, Dogridge remains a preferred choice for climate-resilient viticulture. Similarly, guava, jamun, and sapota production relies on region-specific rootstocks that improve vigor control and stress tolerance. The adoption of dwarfing apple rootstocks M9 and MM106 has expanded apple cultivation and replanting of old orchards in Himachal Pradesh and Jammu & Kashmir. These rootstocks enable high-density planting, improve fruit quality, and enhance per-hectare yield, mitigating the impacts of climate change and increasing both cultivated area and productivity. Beyond conventional roles, rootstocks influence physiological pathways by enhancing stress-related hormone signaling (e.g., ABA), improving drought resilience, providing better anchorage, and adapting to water-limited conditions. Collectively, these traits reduce reliance on irrigation, fertilizers, and chemicals, lowering the carbon footprint and aligning with climate-smart agriculture goals. Looking ahead, integrating traditional breeding with molecular tools and omics-based screening will be pivotal for developing superior rootstock–scion combinations, ensuring sustainable, productive, and climate-resilient fruit production systems.

Keywords: Rootstocks, Climate resilience, Fruit crops, Abiotic stress tolerance, Carbon footprint reduction, Climate-smart agriculture, Breeding and omics approaches, Resilient production systems

Climate Smart Practices for Minimizing Climate Change Impacts on Horticultural Production

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The climate change is a real phenomenon and adversely affects the production, productivity and quality of horticulture produce. The changing patterns of climatic parameters like rise in atmospheric temperature, excess carbon dioxide emissions, changes in precipitation patterns, higher ultra violet radiation and incidence of extreme weather events like heat, salinity, droughts and floods are emerging major threats for production of horticulture crops. Adoption of climate smart practices in horticultural crops are crucial to reduce the impact of climate change by lowering greenhouse gas emissions, improving resource efficiency, ensuring resilient and sustainable production systems. The major climate smart practices are precision farming, protected cultivation, technologies like sensors, drones, and Global positioning system, combined with data analytics, site-specific management, water management in drought areas using drip irrigation, heat stress management practices like selection of heat-tolerant varieties and cultivars, shade nets, planting schedules, crop rotation, improved drainage systems, raised bed cultivation and flood-tolerant crop varieties helps in overcoming altered rainfall patterns, integrated pest, disease and nutrient management approaches and biotechnological interventions like transgenics, CRISPR – Cas helps in development climate resilient varieties and preventing damage from extreme weather events and improving yields despite climate variations. Climate-smart horticulture uses sustainable practices to boost the food and nutritional security of horticulture while increasing its resilience to climate change and reducing greenhouse gas emissions. Climate - smart horticulture offers promising solutions to reduce vulnerability, improve yields, and promote sustainable agriculture practices. Implementing these strategies can contribute to a more climate-resilient horticulture sector ensuring food security and sustainable livelihoods for farmers.

Keywords: Climate change, Precision Horticulture, Protective structures, Climate Smart Horticulture

Climate Change and Horticulture: Impacts, Adaptation and Mitigation Strategies

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Climate change is reshaping horticultural production systems, affecting crop yield, quality, and resource use efficiency. Increasing temperatures, irregular rainfall, elevated CO₂, and more frequent extreme events create serious risks for crops that are highly sensitive to microclimatic variations. To assess and manage these challenges, crop modelling has emerged as a key methodology. Models integrate climate, soil, physiological, and management variables to simulate crop performance under changing conditions. When combined with climate projections and spatial datasets, they help identify crop- and region-specific vulnerabilities. Importantly, they also evaluate adaptation options such as revised planting schedules, stress-tolerant varieties, improved irrigation, and protected cultivation. Beyond adaptation, crop models are valuable for mitigation planning, estimating the role of horticultural practices in reducing greenhouse gas emissions, enhancing energy efficiency, and contributing to carbon sequestration. Recent advances, including integration with remote sensing, artificial intelligence, and decision-support tools, are enhancing model precision and usability. These innovations enable real-time, location-specific recommendations for farmers and policymakers. Strengthening such modelling-based approaches will support the development of climate-resilient and climate-smart horticulture, ensuring long-term sustainability, profitability, and food and nutritional security.

Keywords: Climate resilience, Horticultural crops, Crop modelling, Adaptation, Mitigation, Sustainable practices

Protected Cultivation: Mitigating the Impacts of Climate Variability on Vegetable Crops

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Climate variability, marked by erratic rainfall, extreme temperatures, droughts, floods, and unseasonal weather events, poses a significant challenge to vegetable crop production worldwide. These climatic stresses adversely affect germination, growth, flowering, fruit set, and overall yield, resulting in severe economic losses and threatening food and nutritional security. Protected cultivation offers an effective mitigation strategy by providing a controlled and stable microclimate that shields crops from external climatic extremes.

This paper explores the multifaceted benefits of protected cultivation in addressing climate-related risks, including improved water-use efficiency through technologies like drip irrigation and fertigation, reduction in pest and disease incidence, and the possibility of producing off-season and high-value vegetable crops. By minimizing abiotic stress factors such as heat, cold, and water scarcity, protected cultivation enhances crop productivity, quality, and uniformity. Furthermore, advanced climate-smart technologies such as automated sensors, climate control systems, and integrated pest management (IPM) can be integrated into protected structures to optimize production and reduce reliance on chemical inputs.

Protected cultivation also contributes to sustainable resource management by conserving soil moisture, reducing nutrient leaching, and enhancing input-use efficiency. Although the initial establishment costs are high, economic viability can be achieved through proper crop planning, farmer cooperatives, access to government subsidies, and effective marketing strategies. The adoption of protected cultivation not only mitigates the negative impacts of climate variability but also opens opportunities for year-round production, export-oriented farming, and livelihood improvement. Hence, it serves as a key adaptation and mitigation strategy, fostering climate-resilient and sustainable vegetable production systems.

Keywords : Climate variability, Protected cultivation, Microclimate management, Climate-smart agriculture, Abiotic stress mitigation Sub-Theme: Vulnerability Adaptation and Mitigation Strategies

Local Actions for Climate Resilience: The NICRA Model in Suryapet District of Telangana

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Over the past few decades, climate change has become inevitable. In the present scenario, the focus from yield intensification is switched over to the adaptation to climate change. Climate Resilient Agricultural (CRA) technologies are observed as the best adaptation options available which could enhance the resilience of agriculture. The present study investigates the extent to which CRA technologies are being adopted by the farmers in the villages of Suryapet district in Telangana state where the National Innovations in Climate Resilient Agriculture (NICRA) project was implemented. It further examined the association of profile characteristics of respondents with the extent of adoption of CRA technologies. A structured interview was used to obtain data from 120 respondents. Results revealed medium to high levels of adoption of CRA technologies by the farmers with renovation and/or use of farm ponds, introduction and raising of medium duration variety in red gram viz., LRG-52 and preventive vaccination in livestock among the highly adopted technologies. The profile characteristics viz., farm size, annual income, innovativeness, information seeking behaviour, achievement motivation and Weather Based Agro Advisory Services had positive and significant association with the extent of adoption of CRA technologies by the farmers.

Strengthening Horticultural Productivity under Climate Change through Adaptation and Mitigation

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(Corresponding author: M. Anupriya Chowdary, anupriyamarathi@gmail.com) ABSTRACT

Horticultural crops, including fruits, vegetables, ornamentals, and plantation crops, are highly vulnerable to the impacts of climate change due to their sensitivity to temperature fluctuations, irregular rainfall, and increased incidence of pests and diseases. Rising global temperatures, shifting precipitation patterns, and extreme climatic events threaten crop productivity, quality, and post-harvest stability, thereby endangering food security and farmer livelihoods. Adaptation strategies in horticulture emphasize the development and adoption of climate- resilient varieties, efficient irrigation methods such as drip and micro-sprinklers, protected cultivation, mulching, and integrated pest and nutrient management. Post-harvest technologies, cold chain infrastructure, and diversification of crop species further enhance resilience. Mitigation strategies focus on reducing greenhouse gas emissions and enhancing carbon sequestration through resource-use efficiency, renewable energy applications in greenhouses, organic farming, conservation tillage, and agroforestry-based horticultural systems. The integration of adaptation and mitigation measures, supported by policy interventions and capacity building, is crucial for sustaining horticultural productivity under changing climatic conditions. Strengthening research, extension services, and farmer awareness will play a pivotal role in ensuring that horticulture contributes to both climate resilience and sustainable development.

Keywords: Climate change, Adaptation strategies, Mitigation strategies, Climate resilience, Sustainable horticulture

Sustainable Water Management Practices in Horticultural Crops

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Climate change is increasingly recognized as a major threat to many sectors, i.e., agriculture, coasts, ecosystems, energy, forests, human health, society, transportation, and water resources. Among these, water resource systems are particularly vulnerable, as shifting climatic conditions can significantly alter hydrological cycles. Rising temperatures and elevated evapotranspiration rates intensify water demand, while erratic and unpredictable precipitation patterns further exacerbate water scarcity and distribution challenges. Water is a pivotal input for horticultural crop production, yet it is increasingly threatened by the dual extremes of drought and flooding, both of which are becoming more frequent and severe in the context of global climate change. As such, the implementation of efficient water management practices is indispensable in mitigating the adverse impacts of climatic variability. Techniques such as drip irrigation, which delivers water directly to the roots, help reduce water wastage and increase crop yield. This system ensures that crops receive the right amount of water at the right time, which is particularly important during dry spells. Similarly, adoption of rainwater harvesting is an innovative method that helps conserve water. By collecting and storing rainwater, farmers can supplement their irrigation needs and can boost yields and lower the risk of crop failure, thereby boosting the productivity of arable land. Additional conservation practices such as use of mulch to reduce evaporation from the soil surface, and the installation of moisture sensors to monitor soil humidity, further contribute to water conservation efforts. Strategic crop selection and changes in crop calendars will help farmers adapt to new temperatures and rainfall patterns. It is preferable to use crops varieties that are more resilience to dry spells. Increased agricultural diversification and the better integration of trees, crops, fish and livestock will reduce risk and increase the resilience of farming systems. These integrated approaches not only enhance ecological stability but also offer a buffer against climate-induced risks, thereby fortifying the long-term sustainability of agricultural production systems.

Keywords: climate, water, conservation, drip, rainwater

Theme IV

Socio-Economic Constraints in Adoption of Climate Smart Horticultural Practices

Socio-Economic Constraints in Implementing Integrated Pest Management (IPM) in Horticultural Crops and Solutions for Sustainability

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Integrated Pest Management (IPM) in horticultural crops faces persistent socioeconomic and technical challenges, Expensive technology for adoption, limited access to information, farmer resistance to shifting from conventional practices, weak marketing linkages and the lack of reliable economic thresholds. Additional barriers include poor pest identification, limited biological control options, and insufficient extension support. A digitally enabled, scalable IPM framework to address these barriers is suggested through three integrated components: (1) an Interactive Knowledge Platform offering region-specific pest identification tools, decision-support systems, and curated IPM guidelines; (2) a Community-Based Extension Network facilitating peer-to-peer learning, expert consultation, and collective economic threshold monitoring; and (3) Real-Time Weather-Based Agro-Advisories guided by the RRR principle (Right Time – Right Activity – Right Place), enabling precise interventions aligned with local conditions. The framework reduces information asymmetries, lowers implementation costs, supports predictive pest management, and strengthens institutional mechanisms, representing a paradigm shift toward resilient, technology-driven IPM adoption.

Keywords: IPM, Socioeconomic constraints, Digital agriculture, Technology adoption, Mobile-based platforms, Weather-smart agriculture, RRR principle

Socio Economic Constraints A Barrier for Adoption of Climate Smart Horticultural Practices in Telangana

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A complicated network of interrelated socio-economic barriers that disproportionately impact India's small and marginal farmers the adoption of climate-smart horticultural methods, the financial and economic obstacles are the most powerful. Large initial capital expenditure needed for technology like drip irrigation and protected horticulture is unaffordable to small and marginal farmers. A significant incentive for investment is further eliminated by the lack of a steady market that offers a premium price for produce farmed sustainably. Institutional and societal limitations are also quite important. Many farmers lack the technical know-how to apply climate-smart practices or are simply ignorant of them due to a widespread knowledge and information gap, which is frequently caused by insufficient agricultural extension services. Farmers are also risk cautious due to a deeply rooted aversion to change and preference for conventional techniques. Many farmers, especially women, have limited access to resources and decision-making authority due to institutional problems such gender inequality and unstable land tenure. CSH adoption is frequently restricted to large landowners with greater access to capital and information, highlighting a systemic inequity in the benefits of climate-smart technologies.

Keywords: Climate-Smart Horticulture, Socio-Economic Constraints, Adoption Barriers

Socio-Economic Bottlenecks in Promoting Climate-Smart Horticulture in Telangana

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Telangana, India's youngest state, is gradually emerging as a leading horticultural producer with a diverse portfolio of fruits, vegetables, spices, and flowers. Its agro-climatic diversity makes it well-suited for crops such as Mango, Sweet orange, Acid lime, Turmeric, Chilli, Tomato, Brinjal and Marigold. However, Telangana is also highly vulnerable to climate change impacts—droughts, erratic rainfall, temperature extremes, and groundwater depletion are frequent. Climate-Smart Horticulture (CSH) provides an approach to enhance productivity, resilience, and sustainability, but its adoption in Telangana faces significant socio-economic challenges. This paper examines in detail the barriers to CSH adoption in Telangana across financial, institutional, technological, infrastructural, and social dimensions, with crop-specific examples and regionally relevant policy recommendations. An integrated strategy, based on location-specific climate-smart horticulture concepts and optimized use of available resources, will be most effective in sustaining production under changing climatic conditions.

Keywords: Climate-Smart Horticulture, Telangana, Climate Change Adaptation, Horticultural Crops, Socio-economic Barriers, Policy Recommendations

Adoption of Climate-Smart Horticultural Practices: Socio-Economic Constraints and Strategic Interventions

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Climate change is creating serious challenges in Horticulture, affecting crop yields, quality, and farmer income. Climate-smart horticultural practices (CSHPs) such as improved varieties/rootstocks, protected cultivation, INM, water-harvesting technologies, orchard floor management, mulching, microclimate modification digital & smart technologies (sensors, drones) have been introduced to deal with climate challenges. These practices not only help farmers reduce risks but also improve productivity and sustainability. However, their adoption is still low, especially among small and marginal farmers, due to various socio-economic constraints. One of the biggest barriers is lack of awareness and proper training. Economic challenges of farmer plays a key role in setting up protected structures, smart and digital technologies. Limited access to loans, absence of crop insurance, and poor market facilities further reduce farmers' confidence in investing in such practices. Social factors, includes low education levels, traditional farming methods, and less involvement of women in farm decision-making, also limits the adoption. In addition, weak extension services and insufficient policy support makes it difficult for farmers to get the guidance and incentives they need. An integrated approach in strengthening extension networks, offering financial support (subsidies and easy credits), institutional support, farmer-friendly policies can encourage adoption of advanced technologies. Capacity-building programs, farmer field schools, and participatory approaches can help increase awareness and skills. In the existing climate change phase, adoption of climate-smart horticultural practices can be scaled up for better income for farming communities, self-sufficiency, exports and overall economy of the country.

Keywords: Climate, digital, Horticulture, Farmers, Socio-Economic and Constraints

Socio-Economic Constraints in Adoption of Climate-Smart Horticultural Practices in Telangana

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This study analyses socio-economic constraints affecting the adoption of climate-smart horticultural (CSH) practices in Telangana during 2023–24. Practices such as drip irrigation, fertigation, mulching, protected cultivation, and climate-risk management have demonstrated benefits in improving productivity and water-use efficiency. However, adoption remains uneven, particularly among small and marginal farmers. Telangana's Micro Irrigation Project provides one of the most comprehensive subsidy structures in India, offering up to 100% subsidy for SC/ST farmers and 90% for smallholders. Despite this, farmers continue to face barriers such as high upfront co-financing, collateral requirements, and irregular cash flows, which limit installation and maintenance. By 2023–24, coverage under PMKSY–PDMC had reached approximately 3.26 lakh hectares (drip and sprinkler systems), showing progress but leaving significant potential untapped.

Socio-economic constraints are grouped into five dimensions: (i) financial and risk-related barriers, including limited access to affordable credit, low insurance penetration, and technology adoption risks; (ii) knowledge and service gaps, particularly in fertigation scheduling and protected cultivation; (iii) market and infrastructure challenges, such as price fluctuations and inadequate cold-chain facilities; (iv) tenure and equity issues restricting access for tenant farmers and women; and (v) climate exposure, with high variability in rainfall and temperature intensifying irrigation demand. Addressing these barriers requires targeted credit support, vendor service accountability, Farmer Producer Organization (FPO)-driven input and marketing services, localized infrastructure development, and inclusive extension programs. Strengthening last-mile delivery and equity in policy implementation will accelerate climate-smart adoption, enhance productivity, and promote sustainable horticulture in Telangana.

Keywords: Climate-smart horticulture, Micro-irrigation, Socio-economic constraints, Telangana

Enhancing Climate-Smart Horticulture Uptake in Telangana through Socio Cultural Insights

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Climate-smart horticulture plays a crucial role in enhancing productivity, resource-use efficiency and resilience against climate variability. Despite its importance, adoption of climate-smart practices in Telangana remains limited, largely due to entrenched socio-cultural constraints. This study, conducted across key horticulture-producing districts in Telangana, utilized surveys and focus group discussions with 150 farmers to explore the factors influencing adoption. The findings reveal that traditional beliefs, community norms, and strong peer influence significantly affect farmers' decision-making processes. Many smallholder farmers perceive modern technologies such as drip irrigation, mulching, bio-fertilizers, and protected cultivation as costly, risky, and incongruent with indigenous knowledge systems, resulting in widespread reluctance to adopt these innovations. Moreover, decision-making at the community level discourages individual experimentation, particularly among small and marginal farmers. Gender disparities exacerbate the situation, with women facing limited access to training, credit, and technology, which restricts their active involvement in climate-smart horticulture initiatives. Additional barriers include low literacy rates, limited awareness of climate risks, and inadequate farmer-to-farmer knowledge exchange, all of which further reinforce resistance to change. The study emphasizes that socio-cultural factors are as critical as economic considerations in shaping adoption patterns in the region. To overcome these barriers, an inclusive and participatory approach is essential. Strengthening community-based extension services, fostering farmer-to-farmer learning, promoting successful local role models, and implementing gender-sensitive capacity-building programs are recommended strategies. By integrating cultural understanding with institutional and financial support mechanisms, Telangana can significantly accelerate the adoption of climate-smart horticultural practices. Such progress would enhance the resilience of smallholder farmers, ensure sustainable livelihoods, and contribute to long-term food and nutritional security in the state.

Keywords: Climate-smart horticulture, socio-cultural barriers, Telangana, smallholder farmers, gender disparity, community extension, resilience

Challenges and Constraints in Adopting Climate Smart Practices for Sustainable Mango Production

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Climate change threatens long term mango production by reducing yield, quality, and farmer livelihoods. Climate Smart Horticultural (CSH) strategies such micro irrigation, mulching, integrated fertilizer management, resistant varieties, and post harvest technology might improve resilience, but adoption is still restricted due to socioeconomic obstacles. High investment prices for drip irrigation, cold storage, and other technology frequently inhibit resource poor farmers, which is exacerbated by limited access to credit and subsidies. Weak extension services, limited awareness, and insufficient technical knowledge further limit acceptance, while fragmented landholdings and tenant farming reduce incentive to invest. Social and economic factors such as reliance on conventional norms, risk aversion, and a lack of collaborative action all contribute to sluggish adoption. Market obstacles, such as price instability, inefficient supply chains, and insufficient infrastructure, limit returns, while gender gaps prevent women from participating in climate smart practices. To solve these difficulties, a comprehensive approach is necessary. Affordable technology, inclusive lending systems, and farmer producer organizations must be encouraged. Improved extension, training, and digital advisory platforms can help raise awareness and skills. Improved market linkages and public private partnerships can provide more incentives for investment. To summarize, while CSH approaches show great potential, overcoming financial, social, and institutional barriers is critical for climate resilient, economically successful mango production.

Keywords: Climate change, Climate Smart Horticulture, Micro irrigation, Climate resilient

Facilitating Adaptation: The Role of Agricultural Extension in Overcoming Socio-Economic Constraints to Climate-Smart Horticulture

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Horticulture, one of the most climate-sensitive sectors, faces increasing threats to productivity and profitability from changing weather patterns, including rising temperatures, unpredictable rainfall, prolonged droughts, and extreme events like hailstorms and frosts. These factors directly impact crop growth, quality, and yields. Recent figures illustrate this vulnerability: in Uttarakhand, India, horticultural land declined by 54% and fruit yields by 44% between 2016–17 and 2022–23, while Italy’s extreme summer of 2023 caused an 11.1% fall in the production of fruits, vines, and olives. Such examples reflect a broader global trend where climate change erodes horticultural output, underscoring the urgency of adopting climate-smart practices.

Despite their promise, climate-smart technologies are not widely adopted due to socio-economic challenges. High investment costs for micro-irrigation systems, protected cultivation, or weather-based tools often exceed the capacity of smallholders. Limited access to affordable credit and crop insurance further restricts adoption, while inadequate technical knowledge and weak institutional support slow diffusion. Fragmented market linkages and poor awareness of long-term benefits also discourage farmers. Gender disparities add another layer of constraint, as women often face restricted access to resources, training, and extension services compared to their male counterparts.

Agricultural extension plays a vital role in addressing these barriers and facilitating adaptation. Through training programs, field demonstrations, and participatory learning, extension helps farmers acquire practical knowledge and confidence to adopt new practices. Digital platforms and mobile advisories provide timely information on weather, pest management, and irrigation, enabling quicker decision-making. Extension also connects farmers to subsidies, credit, and insurance schemes, easing financial constraints, while promoting inclusive approaches that ensure participation of women and marginalized groups. By linking farmers with researchers, markets, and policymakers, extension builds innovation networks that strengthen resilience.

Empowering Farmers for Resilient Futures: Socio-Economic Perspectives on Climate-Smart Horticulture

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Climate change has emerged as a major challenge to sustainable horticultural production, necessitating the adoption of climate-smart horticultural practices (CSHPs) to enhance resilience and resource-use efficiency. Despite their potential benefits, widespread adoption of CSHPs remains limited due to persistent socio-economic constraints. Smallholder farmers often face restricted access to credit, subsidies, and affordable technologies, while high initial investment costs discourage adoption. Limited awareness, inadequate training, and weak extension services hinder technical capacity, particularly among resource-poor and marginalized communities. Socio-cultural barriers such as gender inequities, risk aversion, and entrenched traditional practices further reduce willingness to innovate. Additionally, weak market linkages, fluctuating input costs, and uncertain economic returns create disincentives for farmers to shift toward sustainable methods. Overcoming these barriers requires integrated strategies that combine institutional support, inclusive policy interventions, farmer capacity building, and strengthened value chains. Ensuring affordability, accessibility, and social acceptance of climate-smart innovations will be pivotal for fostering widespread adaptation and achieving climate-resilient horticulture.

Keywords: Climate-smart horticulture, socio-economic constraints, adaptation, resilience, sustainable agriculture

Theme V

**Policy and Financial support to Farmers to
Cope with Multiple Climate Risks**

Climate Risk Management in Horticulture: Policy Innovations and Financial Tools

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Farmers are increasingly exposed to multiple climate risks, such as drought, floods, heat stress, salinity intrusion, pest outbreaks and erratic rainfall. These directly threaten crop yields, income stability and food security. Government implement policies and provide financial support for climate-resilient agriculture. This includes: **1. Policy Frameworks:** National Action Plans on Climate Change (NAPCC), National Mission for Sustainable Agriculture (NMSA) (Rainfed Area Development, On Farm Water Management and Soil Health Management), Climate-Resilient Agriculture (CRA) Programs: (adaptation, mitigation and development decisions to promote sustainable development pathways), Market-based instruments (Governments taxes and subsidies on inputs and outputs), Subsidized credits (help farmers adopt climate-smart technologies and practices), Payments for ecosystem services and Conditional social protection measures. **2. Financial Support:** Crop Insurance Schemes (to compensate farmers for yield losses due to extreme weather events – *Padhan Mantri Fasal Bima Yojana (PMFBY)* in India), Credit and Subsidies (for adopting solar irrigation, hydroponics, or protected cultivation), Disaster Relief Funds (for farmers affected by floods, cyclones, or prolonged droughts), Risk-Sharing Mechanisms (Public-private partnerships such as climate bonds, risk pools and mutual insurance funds) and Incentives for Sustainable Practices (reward farmers for carbon sequestration, soil conservation, or water-saving practices). **3. Integrated Approaches:** Social Protection and Safety Nets (Direct cash transfers, food security programs and minimum support price (MSP) mechanisms to stabilize farmer income during climate shocks), Digital Platforms for Financial Inclusion (Mobile banking, digital wallets and blockchain-based platforms to ensure timely compensation and credit delivery) and Community-Based Risk Management (Farmer producer organizations (FPOs) and cooperatives pooling resources for collective risk sharing and bargaining power).

Keywords: Climate, government policies, financial support, farmers, subsidies

Climate Change and Its Implications on Chilli Cultivation: an Extension Perspective

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Climate change has emerged as a critical challenge to sustainable agriculture, and chilli (*Capsicum annuum* L.), one of the most important commercial crops in India, is highly vulnerable to its impacts. Rising temperatures, erratic rainfall, prolonged dry spells, and sudden extreme weather events are increasingly influencing chilli cultivation across major producing regions. These climatic stresses adversely affect flowering, fruit setting, and overall crop yield, while also reducing quality traits such as pungency. In addition, changing weather patterns favour the multiplication of insect pests such as thrips, mites, and aphids, leading to a higher incidence of viral diseases like Chilli Leaf Curl Virus, which severely impact productivity and farmer income. The implications of climate change are not limited to production but also extend to soil health degradation, water scarcity, and input-use inefficiency, thereby intensifying risks for smallholder farmers. Extension strategies must focus on the promotion of climate-resilient and pest-tolerant varieties, efficient water management practices such as drip irrigation, mulching, and fertigation, and the adoption of integrated pest and disease management (IPDM). Equally important are farmer capacity building programs through demonstrations, Farmer Field Schools, and ICT-based climate advisories, which provide timely information on weather forecasts, crop management, and market trends. Furthermore, risk management measures such as crop insurance awareness and collective action through Farmer Producer Organizations (FPOs) can provide economic stability in the face of climate-induced uncertainties. Thus, a participatory and farmer-centric extension system, combining traditional knowledge with modern climate-smart practices, is essential to enhance resilience in chilli cultivation. Strengthening such adaptive strategies will help ensure the sustainability of chilli farming, safeguard farmer livelihoods, and contribute to food and nutritional security in the context of a changing climate.

Keywords: Climate change, Vulnerable, Extension strategies, Integrated Pest and Disease Management

Accelerating a Climate-Resilient Horticultural Sector through Pioneering Innovations from Start Up Ecosystem

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The Indian agricultural and allied sciences landscape is witnessing a major transformative wave driven by the technology driven startup ecosystem. Poised at the forefront of innovation, many of these startups are not only addressing longstanding structural challenges but are also laying the foundation for a more sustainable and prosperous future, by improving productivity, economic prosperity and ecological sustainability across the entire agri- food value chain. Bringing a paradigm shift, dynamic Indian entrepreneurs are today leveraging cutting-edge technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Machine learning, and Data analytics to address agricultural challenges. Currently, more than 2000 Agri-Tech startups are working across a myriad of domains including horticulture, post production, smart warehouse and storage technologies and building innovative solutions to long felt challenges. Agri-tech start-ups empower farmers to make data-driven decisions, adopt modern practices in tandem with existing and traditional knowledge, and access real-time information through their innovative digital solutions. These solutions offer farmers higher profit margins, assistance in product grading and packaging, product traceability, market access, access to quality inputs, and also science-based guidance. Technology driven solutions also contribute to environmental conservation and climate change mitigation through ecologically sustainable practices such as organic and precision farming, agroforestry, crop rotation and water management solutions. This paper will critically evaluate validated use cases of prominent startups and help fast track efforts of the national research and development system to build climate resilience into Horticulture sector as the part of its journey to become a Global Hub for Horticultural Goods. Further, it seeks to suggest a framework to synergize these discrete efforts and solve the concerns of all stakeholders including the researchers-farmer-consumer-business conundrum.

Keywords: Climate-Resilient Horticulture, Artificial Intelligence, Internet of Things

Theme VI

Research Advances and Emerging Technologies

Effect of Nano Fertilizers on Growth, Yield and Quality of Tomato

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In agriculture, nano-nutrient-based fertilizers provide a solution to challenges posed by inorganic fertilizers such as environmental pollution, leaching losses increased salinity, toxicity, and plant damage. These fertilizers are highly soluble, ensure precise nutrient concentrations, and regulate nutrient release due to their large surface area and targeted activity. In this context, a study was conducted to evaluate the effects of nano fertilizers on tomato, the results indicated that among all treatments, 75% RDF + nano NPK @ 10 ml/L (T4) recorded significantly maximum plant height (65.10, 74.45, 85.62 cm), maximum number of compound leaves per plant (24.45, 24.70, 25.13), and maximum number of primary branches per plant (10.66, 13.62, 14.13) at 45, 90 days after transplanting (DAT), and at the final harvest, respectively, compared to the other treatments.

The effect on yield parameters revealed that, T4 recorded significantly maximum fruit length (4.69 cm), maximum average fruit diameter (5.66 cm), maximum average fruit weight (66.20 g), minimum number of days to first fruit set (32.46 days), minimum number of days to first harvest (54.20 days), maximum number of fruits per cluster (6.30), maximum number of fruits per plant (15.66), maximum fruit yield per plant (2.86 kg), maximum fruit yield per plot (18.50 kg), and maximum fruit yield per hectare (31.38 t) compared to the other treatments. The highest total soluble solids (TSS) (4.50 °Brix), highest ascorbic acid content (23.73 mg/100 g), highest reducing sugars (3.4%), and highest total sugars (3.43%), was recorded in T4 while the highest titratable acidity (0.44%) was observed in 50% RDF + nano NPK @ 20 ml/L T7 compared to other treatments. The study revealed that 75% RDF + nano NPK @ 10 ml/L significantly improved growth, yield, and quality parameters in tomato. These findings suggest that nano fertilizers can serve as an efficient and sustainable alternative to conventional fertilizers for enhanced tomato production.

Keywords: Nano fertilizers, Nano NPK, Tomato

Integrated Crop Management Strategies for Sustainable Management of Thrips and Purple Blotch in Garlic (*Allium sativum* L.)”

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Garlic (*Allium sativum* L.) commonly known as “Lashun” which is most cultivated allium species after onion. However, the increasing huge prevalence of purple blotch disease and thrips incidence is a serious hazard that results in losses in both qualitative and quantitative traits. This study aimed to evaluate the potential of combining cultural, biorational and chemical strategies for sustainable pest and disease management. Field experiments were conducted at Medicinal and Aromatic Plant Research Station, Rajendranagar, Hyderabad -SKLTGHU, during Rabi, 2022-23 and 2023-24 to assess efficacy of biorational and chemical against thrips and blotch. The experimental design consists of two factors (N₁:100% N +50 % P + 50% K + PSB @ 5Kg/ha +KSB@ 6Kg/ha; N₂: 50%N +100%P+50%K+ *Azotobactor* @ 5kg/ha+ KSB@ 6Kg/ha; N₃:50%N +50%P+ 100%K+ *Azotobactor* @ 5kg/ha+ PSB @ 5Kg/ha) and bioformulations (B₁: *Trichoderma viride* @ 10ml/l + Neem oil @ 0.5% ; B₂: *Pseudomonas fluorescence* @ 10ml/l + Pongamia oil @ 0.5% ; B₃:*Bacillus subtilis* @ 10ml/l + Sesame oil @ 1%) with ten treatments including control (100% RDF+ Imidacloprid 17.8 SL @ 0.3 ml/lit). Among all treatments the least mean population of thrips (1.94 per plant) and percentage of thrips infestation (1.64%) was recorded under control (imidacloprid 17.8 SL @ 0.3 ml/lit) and number of disease infected plants (1.57 plants / plot) and disease incidence (1.96%/ plot) and the highest yield of 6.52 tonnes per hectare recorded in combined application of 50%N +100%P+50%K+ *Azotobactor* 5kg/ha+ KSB 6Kg/ha along with *Trichoderma viride* 10ml/l + Neem oil 0.5%

Keywords: Thrips, blotch, Neem oil, Trichoderma, pest and disease management

Study of Integrated Nutrient Management (INM) on Quality attributes in Garden Pea (*Pisum sativus* L.)

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This study was undertaken to evaluate the integrated nutrient management on the quality of garden pea tested the experiment was laid out in a randomized block design with three replications. Among the seven treatments evaluated the highest ascorbic acid content (26.66 mg /100 g fresh weight) was recorded in 75% RDF+ FYM (5t /ha) + Vermicompost (1.5 t/ha) + Azotobacter (5kg /ha). The maximum Fiber content (30.21%) was recorded in 75% RDF + FYM (5t /ha) + Vermicompost (1.5 t/ha) + Azotobacter (5kg /ha). The highest protein content (19.86%) was recorded in 75% RDF+ FYM (5t /ha) + Vermicompost (1.5 t/ha) + Azotobacter (5kg /ha). The maximum total soluble solids (17.33 Brix) were recorded in 75% RDF+ FYM (5t /ha) + Vermicompost (1.5 t/ha) + Azotobacter (5kg /ha).

Keywords: INM, Quality parameters, biofertilizers, and Treatments

Impact of climate change in Horticulture: A Scientometric Analysis of The Global Research Landscape Using Scopus Database

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Climate change is a serious threat to horticulture as it alters temperature, cause unpredictable rainfall patterns, and extreme weather conditions that affects crop yields, quality, and overall horticultural sustainability. In view of this paper explores the global trends in research related to climate change and its impact on horticulture. Using a dataset from 1936 to 2025 (up to 20.08.2025) sourced from the Scopus database, 1746 records were analysed through scientometric methods. The analysis revealed that the research on climate change in horticulture had grown exponentially over the last two decades, indicating a growing interest in this field. Out of publications from 112 countries, the highest number of publications came from India with 207 publications which is about 11.86% of the global research literature production in this topic, followed by United States (198), China (160), Spain (135) and Germany (105). The first publication was indexed in 1936 and the highest number of publications indexed in 2024 (169). Climate change, temperature, climate effect, global warming, fruit quality are some of the frequently used keywords. Researchers preferred to publish their findings in the form of articles as out of 1746 publications, 1249 are articles which is about 71.53% followed by conference papers (226) and book chapters (138).

Among the 159 authors contributions the publications, Meland M is the prolific author in this topic with 15 publications followed by Reig G (12), Luedeling E (10), Blanke M (9) and Duan CQ (9). *Acta Horticulturae* is the top source title of publications with 176 followed by *Scientia Horticulturae* (63), *Horticulture* (28), *Frontiers in Plant Science* (25) and *IOP Conference Series Earth and Environmental Sciences* (22). Researchers from INRAE are in top with 50 publications followed by Consejo Superior de Investigaciones Cientificas (41), Universitat Bonn (30), Northwest A and F University (30) and China Agricultural University (27). The analysis of source type revealed that 1340 are journal papers followed by Book series (192), Book (139), Conference proceedings (73) and Trade journal (2).

The study found that English is the dominant language as 1640 publications which is about 93.92% are published in English followed by Chinese (42), Portuguese (23), German (19) and Spanish (12). As far as the open access publications are concerned, 505 papers are available under gold OA followed by Green OA (304), Hybrid Gold OA (107), Bronze OA (79). The leading funding sponsor for research on climate change and horticulture related areas is the National Natural Science Foundation of China (36) followed by European Regional Development Fund (32). India's contribution in this area is vital and the leading universities include Dr. Yashwant Singh Parmar University of Horticulture and Forestry with 20 publications followed by Bihar Agricultural University (19), Bidhan Chandra Krishi Viswavidyalaya (13) and Punjab Agricultural University. This study provides a comprehensive overview of the global landscape, trends, and offers comprehensive insight to researchers, policymakers, and farmers in horticulture, enabling them to effectively address forthcoming climate change challenges.

Keywords: Climate change, Horticulture, Global Warming, Scientometrics

Morphological variation and Genetic Identity of the Banana Scarring Beetle, *Basilepta subcostata* (Coleoptera: Chrysomelidae), in Bihar, India

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Accurate detection and identification of insect pests are fundamental for implementing effective management strategies to mitigate their introduction and spread. This pest is historically established as a major threat to banana cultivation across multiple eastern Indian states, including Bihar. This study presents a comprehensive morpho-molecular characterization of the banana scarring beetle, *Basilepta subcostata*, a significant pest of banana crops, collected from 13 geographical locations across 12 major banana-producing districts of Bihar, India. Four distinct adult color morphs were examined using traditional morphometrics. Univariate ANOVA of twelve morphological characters revealed significant differences among the morphs in body width, antennae length, elytra length, forewing dimensions, and leg lengths, confirming substantial phenotypic variation. Principal Component Analysis (PCA) further delineated the morphological divergence between these morphs. For molecular characterization, the mt*COI* gene was sequenced. The resulting sequences were submitted to NCBI GenBank (Accession Nos.: PV829530-PV829542). Phylogenetic analysis confirmed that all specimens from the geographically dispersed districts of Bihar formed a single, well-supported monophyletic clade with reference sequences of *B. subcostata* from Assam, India, and Nepal, distinctly separating from other *Basilepta* species. Results revealed that all analyzed specimens, despite pronounced morphological diversity, belong to a single species, *B. subcostata*. This study provides a robust basis for the accurate identification of this pest by highlighting the intraspecific morphological plasticity within a genetically homogeneous population, underscoring the necessity of integrating molecular data with traditional morphology for the precise identification of cryptic or polymorphic insect pests.

Keywords: *Basilepta subcostata*, Morphometrics, Molecular characterization, Principal component analysis, Intraspecific variation

Bio Efficacy of Novel Insecticides against Banana Scarring Beetle, *Basilepta Subcostata* (Jacoby) through Laboratory Bioassay

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The banana scarring beetle, *Basilepta subcostata* (Jacoby), is a significant pest distributed across major banana-growing regions of India, with historical reports identifying it as a major pest in multiple states including Bihar, Assam, Uttar Pradesh, and West Bengal. It causes substantial economic losses through foliar and fruit damage. To identify effective control strategies, laboratory bioassays were conducted to evaluate the bioefficacy of thirteen insecticidal formulations against adult beetles. Adult mortality and foliar damage were assessed at 4, 6, and 12 hours after treatment (HAT) using a leaf-dip method.

Results indicated that Thiamethoxam 25% WG and Fipronil 5% SC were the most effective treatments, achieving 100% mortality across all time intervals and exhibiting the lowest cumulative leaf damage (1.67% and 2.23%, respectively). Imidacloprid 17.80% SL, Chlorpyrifos 20% EC, and Fipronil 0.3% G also demonstrated high efficacy, with mean mortality rates exceeding 95%. In contrast, Azadirachtin 0.03% and Chlorantraniliprole 0.4% G were the least effective, showing the lowest mortality and highest leaf damage among all treatments. Probit analysis of the top-performing insecticides revealed that Thiamethoxam 25% WG had the lowest LC₅₀ value (0.103 ppm) and the steepest dose-response slope, confirming its superior toxicity. The study identifies highly effective chemical and botanical insecticides for the sustainable management of *B. subcostata* in banana cultivation systems.

Keywords: *Basilepta subcostata*, Banana scarring beetle, Insecticide efficacy, Probit analysis, Pest management

Bioefficacy, Phytotoxicity and Performance of Psura Gold (Organic Biofertilizer) in Chilli (*Capsicum Annum*) under Horticultural Research Station – Malyal

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Chilli (*Capsicum annum* L) is one the most valuable commercial vegetable crops of India grown throughout the country. India is the largest producer and consumer of Chilli, and is the leading producer of Chilli, contributing close to 45% to the global output with an annual production of 12-14 Lakhs tonnes. For the 2023-24 season, Telangana cultivated 3.92 lakh acres of chilli, producing an estimated 7.94 lakh tonnes, a significant increase from the previous year. Telangana is a major chilli-producing state, with major districts including Khammam, Mahabubabad, Gadwal, Suryapet, and Warangal (Rural). The state's chilli area and production respectively account for 16% and 25% of the total in India. Present studies are to know the Bioefficacy, phytotoxicity and performance of plant based organic fertilizer 'Pasura Gold' on fruit yields of Chilli crop. Trials were undertaken on Chilli crop under Horticultural Research Station agro climatic conditions of Malyal-506101 (Warangal District). Pasura Gold was manufactured under the state of art technology by M/s Pasura Crop Care Pvt.Ltd. For the present studies test samples were provided by the manufacturing company as cited above. This product contains plant-based Nitrogen and Phosphorous as major nutrients toned with Magnesium, Boron, Molybdenum, Zinc etc., which offers pest resistance under adverse weather conditions and the treated plants can with stand low temperatures ad high rainfall conditions. To know the performance of 'Pasura Gold' a trial was laid out in RBD design with 4 treatments and 5 replications with a view to reduce the requirement of chemical fertilizers in this crop. The trial was taken during Rabi with Kashi Anmol as test variety. The treatments consist of application of Pasura gold @ 125 kg/acre applied at 10 DAT+ 60Kg single super phosphate and second dose as top dressing at 50-60 DAT with Pasura Gold @62.5 kg/acre. Side by side other treatments include recommended dose of fertilizers and Control (Farmers Practice). Data were collected on Fruit length, No. of fruits /plant, Yield/ Plant, Yield of Dry fruits (kg /ha) . Phytotoxicity was recorded as per CIB protocols. Results from the above trial indicated that application of Pasura gold@ 125 kg/acre at 10 DAT +60Kg single super phosphate and Second dose as top dressing at 50-60 DAT with Pasura Gold @ 62.5 kg/acre along with application of recommended dose of single superphosphate found to give highest yields compared to recommended dose of fertilizer.

Keywords: Chilli, Bioefficacy, Pasura Gold, Yield

Tissue Culture Strategies for Ivy Gourd (*Coccinia grandis* L.): In Vitro Regeneration and Cytokinin – Mediated Bud Proliferation

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The establishment of an efficient in vitro regeneration protocol for *Coccinia grandis* L. (Ivy Gourd) is of critical importance, particularly as a solution to the shortage of planting material derived from mature stem cuttings. Traditional methods of vegetative propagation rely heavily on stem cuttings, which often face limitations in terms of availability, rooting efficiency, and large-scale multiplication. This constraint has posed a major challenge to the commercial expansion of ivy gourd cultivation. Therefore, tissue culture-based approaches offer a promising alternative, providing a rapid, reliable, and scalable system for the production of healthy and uniform planting materials. In the present investigation, nodal explants of ivy gourd were cultured on Murashige and Skoog (MS) medium supplemented with different concentrations of cytokinins, namely Kinetin (Kn) (0.1–1.0 mg L⁻¹) and Benzyl adenine (BA) (0.1–1.0 mg L⁻¹), both individually and in combination. The primary objective was to assess their effects on bud proliferation and shoot induction responses. Among the various treatments tested, MS medium fortified with 1.0 mg L⁻¹ BA was found to be the most effective. This treatment induced the earliest bud initiation within 5.50 days, produced the maximum number of shoots per explant (1.75), recorded the greatest shoot length (5.71 cm), and achieved a 100% regeneration response.

The micro shoots obtained from this optimized medium were further evaluated for their potential to develop into complete plantlets. Successful shoot proliferation was achieved on MS medium supplemented with BA (1.0 mg L⁻¹) in combination with indole-3-butyric acid (IBA) at 0.3 mg L⁻¹. Root induction was observed most effectively on MS medium containing BA (1.0 mg L⁻¹) and IBA (0.2 mg L⁻¹). These results demonstrate the efficiency and reproducibility of the standardized protocol for generating multiple plantlets from nodal explants. Overall, this newly optimized micropropagation system provides a reliable platform for the large-scale multiplication of superior ivy gourd genotypes, particularly the cultivar Sulabha. The protocol not only addresses the limitations of conventional vegetative propagation but also ensures the availability of quality planting material for commercial cultivation. Its adoption can significantly contribute to enhancing the productivity, profitability, and sustainability of ivy gourd farming, thereby supporting both farmers and the horticulture industry.

Keywords: Ivy gourd, Tissue culture, Cytokinins, Regeneration, Standardized protocol

Evaluation of Tomato, Brinjal And Chilli Rootstocks for The Resistance Against Different Isolates of *Fusarium* Inciting Wilt in Solanaceous Crops

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The study aimed to evaluate the resistance of tomato, brinjal and chilli rootstocks against different *Fusarium* isolates responsible for wilt in solanaceous crops. Ten genotypes, including released varieties and local collections, were tested using a sick plot method. Seedlings were raised in sterilized media and inoculated with spore suspensions of *Fusarium* isolates upon determination of Koch's postulates for confirming the pathogenicity of the isolates. Disease incidence and Percent Disease Index (PDI) were recorded at regular intervals to assess the severity of the infection.

Results showed significant variability in resistance among the genotypes, brinjal genotypes IC618029, LC-1 and LC-2 demonstrated resistance to *Fusarium* wilt, while tomato and chilli genotypes, including IC296468, Arka Vikas and Byadgi Dabbi, were found to be highly susceptible. The combination of *Fusarium* isolates from tomato, brinjal and chilli exhibited increased pathogenicity compared to single isolates. This study highlighted the potential of resistant rootstocks in managing *Fusarium* wilt, which poses a significant challenge to solanaceous crop production. The findings offer valuable insights for developing disease-resistant varieties to ensure sustainable vegetable cultivation.

Keywords: Pathogenicity, *Fusarium* isolates, Resistance, Rootstocks, Disease Incidence

Studies on Standardization of Growing Media and Growing Conditions for Nursery Production of Tomato, Brinjal and Chilli

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Climate change and environmental variability directly influence nursery management in horticultural crops, particularly in sensitive solanaceous vegetables such as tomato, brinjal and chilli. To identify climate-resilient strategies, an experiment was conducted during 2024–25 at the Centre of Excellence, Mulugu, for evaluating five growing media-cocopeat (100%), cocopeat + vermicompost (1:1), cocopeat + vermiculite + perlite (2:1:1), cocopeat + biochar (1:1) and cocopeat + biochar (2:1) under three environments: open field, polyhouse and shade net house. Results revealed distinct environment–media interactions. Polyhouse with cocopeat + vermicompost showed the best overall performance, recording earliest germination (7–8 days), 100% survival, superior vigour and maximum benefit:cost ratio, proving to be highly climate-smart for intensive nursery enterprises. In the shade net house, cocopeat + vermiculite + perlite produced sturdier seedlings with higher stem diameter and vigour, making it suitable for resource-conscious farmers.

In the open field, despite climate fluctuations, cocopeat + vermicompost enabled earlier transplanting (chilli at 45 DAS) and better survival, highlighting its role as a practical low-input adaptation strategy. Overall, protected systems, particularly polyhouse nurseries with enriched organic media, offer the most robust adaptation to climate stress. Shade nets enhance sturdiness at lower cost, while cocopeat + vermicompost in open field provides an accessible entry-level solution. Adoption of these climate-smart nursery interventions can strengthen resilience, ensure quality seedlings and support sustainable horticulture under changing climates.

Keywords: Climate change, Tomato, Brinjal, Chilli, Nursery, Growing media

Generation Mean Analysis Studies in Okra [*Abelmoschus esculentus* (L.) Moench]

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Climate change, with rising temperatures, erratic rainfall, and frequent droughts, threatens the productivity and nutritional security of vegetable crops, including okra (*Abelmoschus esculentum* L.). Developing climate-resilient cultivars with stable yield and quality is therefore essential. The present investigation entitled “*Generation Mean Analysis Studies In Okra [Abelmoschus esculentus* (L.) Moench]” was conducted during 2024–2025 at PGIHS, Mulugu, SKLTSHU, using six generations (P1, P2, F1, F2, BC1F1, BC2F1) from five crosses, evaluated in a randomized block design during Spring– Summer 2025. Traits studied included growth, yield, and nutritional quality attributes. The cross IC39136 x Kashi Lalima was superior for pod yield per hectare, fruit diameter, and iodine content. Such traits contribute to resilience: high pod yield ensures food security, chlorophyll improves photosynthetic efficiency under heat and drought, and iodine and anthocyanin enhance nutritional resilience. Scaling tests revealed significant deviations in A, B, C, and D values, confirming non-allelic interactions beyond the additive–dominance model. The six-parameter analysis showed predominance of non-additive gene action (dominance [h], dominance x dominance [l], additive x dominance [j], crucial for yield stability under variable climates. EC329370 x Parbhani Kranti showed strong dominance ($h = 484.76$) and duplicate epistasis for pod yield ($m = 316.04$ g), while IC42456 x Parbhani Kranti exhibited positive dominance and epistasis for pod yield, chlorophyll, and iodine content. Heterosis analysis revealed that IC42456 x Kashi Lalima and EC329370 x Parbhani Kranti expressed high hybrid vigour, with EC329370 x Parbhani Kranti showing 155.81% heterosis for pod yield per plant and 52.38% for pods per plant, coupled with low inbreeding depression. Overall, IC39136 x Kashi Lalima and EC329370 x Parbhani Kranti were identified as promising crosses for breeding climate-resilient okra cultivars. Exploiting heterosis and epistasis can accelerate the development of high-yielding, nutritionally enriched okra with adaptability to climate change.

Keywords: Okra, climate resilience, generation mean analysis, heterosis, gene action, epistasis, nutritional quality, yield stability

Generation Mean Analysis Studies in Tomato (*Solanum lycopersicum* L.) for Mitigating Climate Change

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Climate change can influence generation mean analysis in tomato by altering trait expression such as growth rate, flowering, yield and fruit quality under elevated temperatures, variable rainfall and increased CO₂. The current study, "Generation mean analysis studies in tomato (*Solanum lycopersicum* L.)," was carried out at Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, during two seasons under changing climatic conditions. A total of six generations (P₁, P₂, F₁, F₂, BC₁F₁ and BC₂F₁) developed from seven diverse parents (EC632944, EC631378, EC631477, EC631455, Pusa Ruby, MHTO100 and MHTO101) and five promising hybrids were evaluated in this study. Significant differences among generations were recorded for key traits, with F₁ hybrids outperforming parents, particularly for fruit yield and fruit number. Cross (EC631477 × Pusa Ruby) and Cross (EC631455 × MHTO 100) exhibited superior per se performance, while scaling tests revealed epistatic interactions. The six-parameter model confirmed that non-additive gene actions, especially dominance and epistasis, were predominant, though additive effects were also significant. Cross (EC631455 × MHTO 100) consistently showed strong positive dominance and epistasis for yield, highlighting its hybrid potential even under climate-induced stress environments. Elevated temperatures hasten flowering and fruit harvest but reduce fruit set and yield stability, while drought stress limited plant height, branching and leaf area. Adaptive strategies, including the use of climate-resilient hybrids such as, Cross (EC631455 X MHTO100), protected cultivation, stress-tolerant rootstocks and efficient water-nutrient management, can mitigate adverse effects. Mitigation measures like carbon-smart practices, mulching, organic amendments and climate-based crop modelling can further stabilize productivity. Overall, the integration of generation mean analysis with climate-resilient strategies identifies Cross (EC631455 × MHTO 100) as a robust combination for improving yield and fruit quality, offering a promising pathway to sustain tomato production under changing climates.

Keywords: Climate change, Tomato, Generation mean analysis, Adaptation, Gene action, Mitigation

Genetic Evaluation and Divergence Studies in Brinjal (*Solanum Melongena* L.) under Southern Telangana Conditions

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The study entitled “Genetic evaluation and divergence studies in Brinjal (*Solanum melongena* L.) under Southern Telangana condition” was carried out at the College of Horticulture, Rajendranagar, Telangana during *Rabi*, 2024–25, to assess genetic variability, character association and divergence among twenty brinjal genotypes for yield and related traits. Significant variation was observed among the genotypes. The highest fruit yield per plant and per hectare were recorded in IC-354511, while traits such as number of fruits per plant, fruit length and average fruit weight exhibited high heritability coupled with high genetic advance, indicating the role of additive gene action and their suitability for selection. Correlation and path analysis revealed that average fruit weight and number of fruits per plant exerted the strongest positive influence on yield. Divergence analysis showed fruit length, number of fruits per plant and days to 50% flowering as the major contributors to genetic diversity, suggesting their importance in parent selection for hybrid development. In the context of climate change, where rising temperatures, irregular rainfall and biotic stresses threaten horticultural productivity, the identification of resilient brinjal genotypes is crucial. Genotypes with early flowering, higher fruit set and stable yield performance can act as adaptation strategies, minimizing yield losses under stress conditions. The utilization of genetically diverse parents for hybridization enhances resilience and contributes to mitigation strategies by reducing vulnerability and supporting climate-smart horticulture. Overall, the study highlights key traits and promising genotypes that can be effectively utilized in brinjal breeding programs, not only for yield improvement but also for developing climate-resilient horticultural systems.

Keywords: Brinjal, Genetic variability, Genetic divergence, Climate change, Adaptation strategies, Mitigation strategies

Studies on Organoleptic Evaluation and Benefit Cost Ratio of Bael (*Aegle marmelos* Correa) RTS Beverage Blended with other Fruits

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Horticultural systems are increasingly vulnerable to climate variability which manifests through erratic rainfall elevated temperatures and post-harvest losses that collectively threaten nutritional security and rural livelihoods. Climate change adaptation in horticulture requires not only resilient production practices but also innovative post-harvest and value-addition strategies that minimize waste and enhance farmer income. In this context, indigenous and underutilized fruits such as bael (*Aegle marmelos* Correa) offer significant potential as climate-resilient resources due to their adaptability to marginal soils, drought tolerance, and nutritional richness.

The present investigation assessed ready-to-serve (RTS) beverages prepared from bael blended with guava, grape, and dragon fruit juices, focusing on organoleptic properties and benefit–cost analysis during 60 days of storage. The results revealed that the 25% bael + 75% grape blend exhibited superior consumer acceptability and the highest benefit–cost ratio (3.28:1), demonstrating the dual advantage of nutritional quality and economic viability. Beyond these specific results, the study highlighted broader adaptation and mitigation pathways: reducing 20–25% post-harvest losses, diversifying value chains, promoting low-carbon food alternatives to synthetic beverages, and creating livelihood resilience for smallholders. This study therefore positions bael-based RTS beverages as a case model for integrating indigenous biodiversity into holistic climate change mitigation and adaptation strategies in horticultural systems.

Keywords: Bael, RTS, Climate change, Nutrition, Post-Harvest

Reinventing Tradition: Fortified Rice Starch Films with Vegetable Juice for Paper Sweet

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Paper sweet is wafer-thin rice starch based edible film stuffed with sugar/jaggery powder, clarified butter and chunks of dry fruits and/or nuts. Rice starch based edible film has only nutrition values of rice and no pronounced quantity of micro nutrients present in the film. Fortification of rice-based films was carried out to improve nutritional and sensory properties using various vegetable juice. *Jaya* variety bold rice batter added with juice in separate flat containers, a thin cotton cloth was dipped in batter, spread over the hot curved surface of inverted pot, optimized process parameters based on textural properties and also evaluated nutritional, sensory and storage studies. Mechanical strength of vegetable juice fortified films was reduced compared to the film without fortification whereas water solubility and nutrition of fortified film increased in comparison to the film without fortification. Sensory qualities of fortified paper sweet were superior to without fortification.

Keywords: vegetable, edible films, fortification, paper sweet, traditional sweet

Studies on Effect of Commonly Available Food Sources on Extension of Vase Life of Gladiolus (*Gladiolus Grandiflorus* L.) cv. Swarnima

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Longevity of cut flowers is one of the main challenges of florists today, to enhance the vase life of cut gladiolus spikes, keeping in mind the environmental pollution caused by chemical preservatives, in this present study in place of chemical preservatives, commonly available food sources T₁: Sugar - 10 g/l, T₂: Sugar - 20 g/l, T₃: Coconut Water - 25%, T₄: Coconut Water - 50%, T₅: Sprite - 50 ml/l, T₆: Sprite - 100 ml/l, T₇: Honey - 5%, T₈: Honey - 10%, T₉: Control (Distilled water) were used. Among all the food sources used in study, sprite 100 ml was best in extending the vase life of gladiolus spikes. which recorded best results in respect of high water uptake (22.62, 14.62, 11.29 g/f), transpirational loss of water (20.82, 13.00, 10.28 g/f), water balance (6.80, 6.41, 6.01 g/f), maximum per cent of fresh weight change (106.69, 98.73, 89.36 %), low optical density of vase solution (0.037, 0.042, 0.054) on 2nd, 4th and 6th day of vase life, respectively and less number of days for first floret opening (1.69 days), greater diameter of basal floret (10.33 cm) and maximum longevity of basal floret (2.63 days), maximum number of florets opened on spike when basal floret is fresh (2.33) and maximum number of florets opened per spike at the end of vase life (10.89), highest vase life (9.33 days) and floret opening percentage (94.69 %) was registered in Sprite 100 ml. Whereas high benefit cost ratio was recorded in Sugar 20 g (3.30). Therefore Sprite 100ml /l can be used for enhancing the vase life of gladiolus.

Keywords: Gladiolus, Vase life, Food sources, Preservatives, Florets

Biodegradable Plastic Mulch Sheets for Raised Beds

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Mulching, a fundamental practice for soil moisture retention, weed suppression, and temperature regulation, is often implemented with thin commercial mulch sheets in raised beds made of polyethylene. LDPE mulch sheets, LLDPE mulch sheets and bioplastics (Bio-PE, Bio-PP, Bio-PET, Bio-PTT and Bio-PA), PLA, PCL, PLA-PBAT mulch sheets were developed in continuum. However, these sheets are hard to remove and often tear while removing. Farmers generally resort to either till these sheets in the soil (as they add labour costs) or burn them, which show detrimental effects on the soil and environment as whole. When burnt, releases greenhouse gases. Recent developments include the development of time release mulch sheets, stretchable mulch sheets, recycled plastic mulch sheets, multilayered mulch sheets etc. based on the purpose and requirement. More recent advances are the development of biodegradable mulch sheets prepared from agricultural and horticultural industrial wastes, which generally go to the landfill and indeed trigger methane emission. The development of these biodegradable alternatives could mitigate the environmental impact associated with plastic-based mulches and enhance sustainable farming practices. This paper aims to explore the potential of creating innovative biodegradable mulch sheets, derived from agricultural and horticultural wastes, which offer an eco-friendly solution to the challenges currently faced in mulching practices. It will be evident that biodegradable mulch sheets not only reduce pollution but also promote the circular economy within agricultural and horticultural landscape, benefiting both the environment and farming communities.

Keywords: Mulch sheets, Petrochemical, Bioplastic, Biodegradable

Collection and Conservation of *Momordica Cymbalaria* Hook.F.: An Underexploited Potential Vegetable in the Era of Climate Change

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Momordica cymbalaria Hook.f., a lesser-known and underutilized tuber-forming cucurbit of the family Cucurbitaceae, holds considerable ethnobotanical and nutritional significance. In India, it is locally recognized by various vernacular names “Karchikai” and “Madagalikai” in Karnataka, “Athalakakai” in Tamil Nadu, and “Kasarakayee” in Andhra Pradesh and Telangana, reflecting its cultural importance across regions. *M. cymbalaria* fruits are a nutritionally dense vegetable, offering enhanced levels of fibre, calcium, potassium, sodium, and vitamin C over bitter melon. The cultivation of *M. cymbalaria* is primarily constrained by the lack of efficient propagation methods. The species primarily propagates through perennial tubers, but their numbers are limited, and only a few survive in the soil to regenerate single plants in the following season. Sexual reproduction is equally inefficient, hampered by a low number of dormant seeds per fruit and a consistently poor germination rate, which curtails effective propagation.

Furthermore, propagation by seed is severely constrained by low fruit seed count, seed dormancy, and poor germination rates. Thus, the species predominantly grows in the wild by the tribal communities and in the fields by farmers. However, the germplasm is at risk due to the prevailing global warming and climate change. Recognizing its importance, the Indian Council of Agricultural Research–National Bureau of Plant Genetic Resources (ICAR–NBPGR), Regional Station, Hyderabad, has surveyed and collected a total of twenty-one accessions of *M. cymbalaria*. The germplasm collected represents a wide distribution in the states of Karnataka, Andhra Pradesh, Tamil Nadu and Maharashtra. These accessions exhibit substantial variability in fruit characters, underscoring the rich genetic diversity within the species. Conservation efforts for this species have also been extended to in vitro conservation at the *In Vitro* Genebank of ICAR-NBPGR, New Delhi. Considering its nutritional and socio-economic importance, urgent action is required to systematically collect, characterize, and conserve *M. cymbalaria*. Implementing a complementary conservation approaches using field genebank, in vitro genebank and cryo genebanks offers a complementary strategy to safeguard its genetic diversity and support future crop improvement and sustainable food use.

Keywords: *Momordica cymbalaria*, Climate change, conservation

Role of Biochar in Sustainable Horticulture Crops

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Achieving the sustainable development goals, mitigating global warming, and reaching carbon neutrality requires a drastic reduction in Greenhouse Gas emissions and carbon capture and storage (CCS) techniques to remove CO₂ from the atmosphere or avoid its emission. Biochar is a "stable form of carbon produced by the pyrolysis of biomass," emphasizing its role in carbon sequestration. Sustainable horticulture involves adopting eco-friendly strategies to boost yields while maintaining environmental conservation. Biochar (BC), a carbon rich material, is widely used in farming to improve soil physical and chemical properties and as an organic substitute for peat in growing media. BC amendments to soil or growing media improve seedling growth, increase photosynthetic pigments, and enhances photosynthesis, thus improving crop productivity. Soil BC incorporation improves abiotic and biotic stress tolerance, which are significant constraints in horticulture. BC application also improves disease control to an acceptable level or enhance plant resistance to pathogens. Moreover, BC amendments in contaminated soil decrease the uptake of potentially hazardous metals, thus minimizing their harmful effects on humans. Treatment with 1kg/m² (10t/ha) biochar at 15-20cm depth led to a significant increase of 35.4%, 98.1%, 28.4%, and 35.2% in the mean fresh weight of radishes, lettuce, tomatoes, and sweet peppers and 2kg/m² (20t/ha) was reported in an improvement of 70.7% in radishes, 126.1% in lettuce, 38.4% in tomatoes, and 95.0% in sweet peppers (González-Pernas, F.M. 2022). Biochar represents a powerful tool for enhancing soil health and plant growth in horticulture. Its ability to improve soil structure, increase water and nutrient retention, and promote sustainable practices makes it a valuable asset for modern horticulture.

Keywords: Biochar (BC), Greenhouse Gas, Carbon Capture and Storage

Genetic Variability (GCV and PCV), Heritability and Genetic Advance over mean studies in F₃ generation of Ridge gourd

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Evaluation of F₃ progenies with five parents (Arka Sumeet, Konkan harita, Jaipur long, Saloni-5 and NRG-9 and their three promising F₁ hybrids viz., cross-I P₁ x P₂ (Arka sumeet x Konkan harita), cross-II P₁ x P₃ (Arka sumeet x Jaipur long) and cross-III P₄ x P₅ (Saloni-5 x NRG-9) was studied two replications with randomized block design during summer, 2022 at All India Coordinated Research Project (Vegetable Crops), Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.). The high genotypic coefficient Variation (GCV) and high phenotypic coefficient variation (PCV) observed traits for number of branches per vine, sex ratio in cross-III, number of fruits per vine, fruit yield per vine, fruit yield per plot and fruit yield per ha. The high heritability with high genetic advance as per cent of mean was observed for the characters number of branches per vine, node number at which first male flower in cross II, node number at which first female flower in cross-I, sex ratio in cross-III, number of pickings, length of fruit except cross-I, weight of fruit except cross- II, number of fruits per vine, fruit yield per vine, fruit yield per plot and fruit yield per ha. The high variability (GCV&PCV), heritability and genetic advance showed traits less environmental factors influence for better scope through selection for breeding programme.

Keywords: Variability, Genotypic Coefficient Variation, Heritability, Genetic advance

Performance of Broccoli (*Brassica oleracea* var. *italica* L.) varieties under different Plant Densities in Telangana.

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The present investigation entitled “Performance of broccoli (*Brassica oleracea* var. *italica* L.) varieties under different plant densities in Telangana” was carried out during *Rabi* 2024–2025 at PGIHS, SKLTGHU, Mulugu, Telangana, using a Factorial Randomized Block Design with four varieties (Palam Samridhi, Palam Vichitra, Pusa Purple Broccoli-1, Saki) and four spacings (S₁: 60 cm × 30 cm, S₂: 60 cm × 40 cm, S₃: 60 cm × 50 cm, S₄: 60 cm × 60 cm). The study aimed to identify a suitable variety and optimize plant densities under Telangana conditions, while also recognizing the importance of crop management in the context of climate change. Palam Samridhi recorded superior growth, yield and quality traits, while 60 cm × 60 cm spacing favoured better plant performance and quality and 60 cm × 30 cm spacing ensured maximum yield per hectare. The best interaction was Palam Samridhi + 60 cm × 60 cm for growth and quality and Palam Samridhi + 60 cm × 30 cm for yield. These findings have strong implications in the light of climate change, which poses significant challenges to vegetable production due to erratic rainfall, temperature fluctuations and soil health degradation. Broccoli, being a cool-season crop, is highly sensitive to climatic variability, making the choice of suitable variety and spacing critical for ensuring stable yields under changing agro-climatic conditions. Adoption of resilient varieties like Palam Samridhi, along with optimized planting densities, represents an adaptation strategy to enhance resource-use efficiency, reduce crop failure risk and sustain productivity. Moreover, higher biomass accumulation and quality parameters such as chlorophyll and ascorbic acid contents highlight the crop’s potential role in mitigation, contributing to carbon sequestration and improved nutritional security. Thus, the study emphasizes that varietal selection and plant density standardization are not only agronomic interventions but also climate-smart horticultural strategies, aiding both adaptation and mitigation under Telangana conditions. Integrating such findings into climate-resilient horticulture can ensure sustainable broccoli cultivation and contribute to long-term food and nutritional security.

Keywords: Broccoli, Varieties, Plant density, Climate change

Flowering Behaviour, Fruit Set and Assessment of Phenology in Mango (*Mangifera indica* L.) cv. Banganpally using Remote Sensing Techniques

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The present study investigated the phenology, flowering behavior and fruit set of the Banganpalli mango cultivar using remote sensing techniques during the 2024–2025 growing season at the Fruit Research Station (FRS), Sangareddy, Telangana. Seasonal variations in vegetative and reproductive phases of Banganpalli were monitored using vegetation indices derived from remote sensing including NDVI, LSWI, CI, RECI, EVI and SAVI. Remote sensing analysis showed that Banganapalli had more pronounced seasonal variation in vegetation indices with notable dips during flowering and recovery during fruit development and monsoon indicating a cyclical vegetative growth pattern aligned with reproductive phases. These fluctuations reflected changes in canopy vigour, chlorophyll content and moisture status associated with phenological transitions. The most prominent Mango variety Banganpalli exhibited reproductive development with flower bud differentiation on first fortnight of December, panicle emergence by second fortnight of December with full bloom by second fortnight of January and fruit set by second fortnight of February during the year 2024. The remote sensing analysis effectively captured these phenological shifts highlighting the cultivar's sensitivity to seasonal environmental variations. The findings underscore the potential of integrating remote sensing tools in cultivar-specific mango phenology monitoring and precision orchard management particularly for optimizing inputs and improving productivity in Banganapalli mango cultivation. These insights suggest that Banganpalli early flowering and seasonally responsive phenology can inform targeted agronomic practices to improve its productivity.

Keywords: Remote sensing, Phenology, NDVI-Normalized Difference Vegetation Index, LSWI-Leaf surface water index, CI-Chlorophyll index, Re-CI-Red edge Chlorophyll Index, EVI-Enhanced Vegetation Index, SAVI-Soil-Adjusted Vegetation Index.

Crop Modelling Approaches and Applications in Vegetable Crops

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Vegetable crops, being highly sensitive to climatic variability, soil conditions, and management practices, face increasing challenges under the current scenario of climate change and resource constraints. Crop modelling has emerged as a valuable tool for understanding crop–environment interactions, predicting growth and yield, and evaluating management strategies in diverse vegetable production systems. Different modelling approaches have been developed and applied, each with distinct strengths and limitations. Empirical or statistical models, based on observed relationships between climate variables and yields, provide rapid assessments but are often limited in predicting crop performance under future climate scenarios. Process-based models (PBMs), such as the Decision Support System for Agrotechnology Transfer (DSSAT), the Agricultural Production Systems Simulator (APSIM) and the FAO AquaCrop model, simulate physiological processes including photosynthesis, respiration, water balance, and nutrient uptake, thereby offering more mechanistic insights into vegetable crop responses. Recent advancements also include machine learning (ML) and artificial intelligence (AI)-based models that utilize large datasets from weather, soil, and remote sensing to enhance prediction accuracy and decision support. The applications of crop modelling in vegetable crops are wide-ranging. They include yield forecasting, optimization of planting dates, irrigation scheduling and nutrient management. Climate change impact assessments using crop models provide insights into how rising temperatures, irregular rainfall and elevated CO₂ levels influence the productivity of crops such as tomato, potato, onion and chilli. Integration of crop models with Geographic Information Systems (GIS) enables spatial analysis, identifying shifts in geographical suitability and potential hotspots of vulnerability. Additionally, crop–climate–pest linked models are being used to forecast disease outbreaks like late blight in potato and anthracnose in chilli, aiding in timely management. Furthermore, modelling supports plant breeding by virtually screening stress-tolerant varieties before extensive field evaluation. Overall, crop modelling approaches serve as essential decision-support systems in vegetable research and production. By integrating empirical, mechanistic, and AI-driven approaches with field validation, they contribute to developing climate-resilient production systems, ensuring yield stability, resource-use efficiency, and sustainability in vegetable cultivation.

Keywords: Vegetable crops, Crop modelling, DSSAT, APSIM, AquaCrop, Climate change, Yield forecasting, Geographic Information Systems (GIS), Machine learning, Artificial intelligence, Climate resilience, Pest–climate models, Sustainable production

Urban Vertical Farming - A Way Forward for Future India and Environment

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Urban vertical farming can produce food in a climate-resilient way in urban areas while releasing zero pesticides, fertilizers, using less land and water than traditional agriculture. It can fulfil daily consumer needs for healthy, fresh goods while also contributing to resilient food systems, especially in and around heavily populated regions. Emerging issues like food security, urbanization, agricultural scarcity, food miles and increasing emissions of greenhouse gases illustrate the need for vertical farming. Urban vertical farming an eco-friendly, energy-saving and promising alternative to conventional farming, will be able to feed the world's growing population in the future. It is distinct to growing fruits and vegetables on large farms and then transporting them over vast distances in trucks and planes, may serve local products from neighborhood buildings. Urban farming offers excellent opportunities for the sustainable development of places such as urban cities, as well as a form of moral support economically, morally and environmentally. It also addresses the recent changes carried to the general urban landscape by the COVID-19 Pandemic. Furthermore, from an environmental point of view, urban farming improves and allows for soil conservation, provides microclimate conditions and enhances biodiversity in environmental consciousness, reduces pollution and global warming and boosts biodiverse environmental awareness. The fundamental goal is to introduce numerous functions that sustain the ecosystem, as well as how they affect assessable advantages for urban masses at various scales of solutions inside that scope of urban vertical farming and promotes better health for urban peoples.

Keywords: Urban vertical farming, Global warming, Food security, Environmental awareness

Nano Fertilizers as Adaptation and Mitigation Tools: Evidence from Tomato Cultivation under Changing Climate

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Climate variability and extreme weather events are increasingly disrupting horticultural productivity, particularly in vegetable crops such as tomato. Sustainable nutrient management practices are vital for building resilience and reducing environmental impacts in the face of climate change. A field study entitled “Influence of Nano Urea Plus and Nano DAP Applications on Growth, Yield and Quality of Tomato (*Solanum lycopersicum* L.)” was conducted during Spring–Summer 2025 at the Centre of Excellence, Mulugu, Siddipet, Telangana, using a Randomized Block Design with nine treatments and three replications. Nano urea plus and nano DAP were applied as foliar sprays at two critical growth stages along with recommended fertilizer doses.

The results revealed that nano fertilizer applications significantly improved vegetative growth, hastened flowering, enhanced fruit set and increased fruit yield compared to conventional fertilizer practices. Quality parameters such as total soluble solids, ascorbic acid content and fruit firmness were also superior under nano-based treatments. Beyond productivity, reduced bulk fertilizer usage with nano formulations highlights their potential in lowering nutrient losses, minimizing greenhouse gas emissions and improving nutrient-use efficiency.

This study demonstrates that nano fertilizers, particularly nano urea plus and nano DAP, can serve as effective adaptation and mitigation tools in tomato cultivation. By enhancing yield, improving quality and reducing environmental footprints, nano formulations emerge as a promising climate-smart innovation for resilient and sustainable horticulture.

Keywords: Climate change, nano fertilizers, nano urea plus, nano DAP, tomato, adaptation, mitigation



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