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MAPPING VULNERABILITY OF RICE PRODUCING DISTRICTS TO CLIMATE CHANGE IN MAHARASHTRA: AN ENDEAVOUR TO MANIFEST REGIONAL VARIATION

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Abstract

The vulnerability of rice production to climate change in Maharashtra's districts necessitated an assessment, with historical data sourced to evaluate sensitivity, exposure, and adaptive capacity indicators. Employing the Intergovernmental Panel on Climate Change (IPCC) methodology, a composite vulnerability index was computed for 11 major rice-producing districts. The process involved normalizing variables for comparability and assigning weights based on sensitivity, exposure, and adaptive capacity through principal component analysis. Districts were subsequently categorized as high, moderate, or low vulnerability regions based on mean and standard deviation (SD) norms. The analysis revealed varying exposure levels during the rice growing season, with Ratnagiri having the highest (0.54) and Pune the lowest (0.30). Chandrapur exhibited the greatest sensitivity (0.68), whereas Ratnagiri displayed the lowest (0.02). Nashik demonstrated the highest adaptive capacity (0.84), followed by Bhandara and Nagpur, while Ratnagiri had the lowest (0.12). Overall, Chandrapur emerged as the most vulnerable district (0.65), while Nashik was the least vulnerable (0.24) among rice-producing districts. This variability underscores the importance of prioritizing region-specific research and development efforts and implementing tailored adaptation strategies in Maharashtra to mitigate adverse impact of climate change.

Keywords: Rice, climate change, vulnerability, exposure, sensitivity, adaptive capacity

Introduction

The degree of vulnerability in a system is shaped not solely by the extent of climate change experienced by the system, but also by the system's sensitivity to these changes and its ability to adapt to evolving climatic conditions. Global climate change is manifesting in significant and long-term alterations across the planet, as observed in various key indicators. Atmospheric carbon dioxide levels had reached 421 parts per million by 2022, a primary driver of global warming. Notably, 2020 tied with 2016 as the hottest year on record, highlighting the sustained trend of rising temperatures (NASA, Global

Climate Change: Vital Signs of the Planet, 2022). India's vulnerability to climate change has escalated, with the nation currently ranking as the 5th most vulnerable globally, a stark contrast to its 14th position in 2017 (Germanwatch, 2020).

This study is centered on Maharashtra, the third-largest state in India in terms of land area. Maharashtra experiences its monsoon season from June to October, with the year 2022 witnessing a noteworthy 119.8 per cent (1,287.9 mm) of normal monsoonal rainfall. Additionally, during the *kharif* season of 2022-23, sowing was completed on 157.97 lakh hectares, a decrease compared to the previous year's 163.79 lakh hectares, as reported

in the economic survey of Maharashtra for 2022-23. Within Maharashtra, rice takes the forefront as the dominant crop, with the statistics for the year 2022-23 revealing a substantial cultivation area of 1555.32 thousand hectares, an impressive production of 3453.84 thousand tonnes, and a noteworthy productivity rate of 2220.66 kg per hectare (Department of Agriculture, Govt. of Maharashtra, 2022).

This study specifically focuses on 11 major rice-growing districts in Maharashtra, a choice made purposefully due to their substantial contributions, collectively representing 92.63 per cent of the total rice cultivation area and 94.25 per cent of the overall rice production. Over time, Maharashtra has experienced numerous administrative adjustments. Within the chosen districts, the original districts, namely Bhandara and Thane, which were in existence at the outset of the 1990-91 study period, have undergone a division process over the years, resulting in the creation of two new districts, namely Gondia and Palghar, respectively. To streamline the analytical process, the data from these newly carved-out districts has been amalgamated with the data from the districts as they existed in 1990-91, simplifying data analysis for consistency.

Globally, economic losses stemming from natural disasters are on an upward trajectory, and the agriculture sector stands as a particularly vulnerable target. Research conducted by Kelkar *et al.* underscores a pronounced reduction in rice production in Maharashtra attributed to shifting climatic factors. In light of the critical nature of this challenge, a comprehensive study entitled "Mapping Vulnerability of Rice-Producing Districts to Climate Change in Maharashtra" has been initiated. The study's significance lies in its potential to pinpoint the precise areas within Maharashtra that are most susceptible to the effects of climate change. This information is expected to play a pivotal role in shaping policies and strategies aimed at effectively mitigating the detrimental impacts of climate change on rice production in the state.

Materials And Method

Vulnerability, as outlined by the IPCC in 2007, is the extent to which a system is prone to, or

unable to cope with, adverse effects of climate change, which includes climate variability and extremes. It is the function of the character, magnitude and rate of climate variation to which a system is exposed, the sensitivity and adaptive capacity. Exposure is the nature and degree to which a system is exposed to climate change. Sensitivity is the degree to which a system is adversely affected by climate change. Adaptive capacity represents the ability of a system or region to better adjust to climate change (IPCC, 2007).

The pivotal stage in vulnerability assessment revolves around the identification of apt indicators that can effectively capture the intricacies of the system under scrutiny. In this research, a range of indicators related to exposure, sensitivity, and adaptive capacity concerning climate change are utilized to evaluate the vulnerability of districts in Maharashtra that engage in rice production. These specific indicators and their details are succinctly summarized in Table 1 for convenient reference and analysis within the study.

The study's primary focus lies in evaluating the prevalence of various meteorological phenomena, specifically rainy days (rainfall = 2.5 mm), heavy rainfall (64.5 mm to 115.5 mm), very heavy rainfall (115.6 mm to 204.4 mm) as well as slight (-11% to -25% rainfall deficit) and moderate meteorological drought (-26% to -50% rainfall deficit), within the defined timeframe of 1990 to 2021. These assessments are based on criteria set forth by the Indian Meteorological Department (IMD) and are concentrated on the *kharif* season (June to October). In the pursuit of quantifying the trend's magnitude and understanding the potential presence of statistically significant trends in hydro-meteorological variables such as rainfall and rainy days within the *kharif* season from 1990 to 2021, particularly concerning climate change, Sen's slope estimator and the non-parametric Mann-Kendall (MK) test has been applied, respectively. The study sought to evaluate the instability and growth in both the cultivated area and the yield of rice within the region over the period from 1990 to 2022. This assessment was carried out by applying Cuddy-Della Valle instability index and Compound Annual Growth Rate (CAGR), respectively. Potential losses in rice

Table 1 Indicators and their functional relationship with component

S. No.	Indicators	Component	Unit	Functional relationship with component
1.	Exposure	a) Trend in <i>kharif</i> rainfall	Trend coefficient	-
		b) Trend in rainy days in <i>kharif</i>	Trend coefficient	-
		c) Frequency of heavy rainfall events in <i>kharif</i>	No. of events	+
		d) Frequency of very heavy rainfall events in <i>kharif</i>	No. of events	+
		e) Slight meteorological drought in <i>kharif</i>	No. of year	+
		f) Moderate meteorological drought in <i>kharif</i>	No. of year	+
2.	Sensitivity	a) Instability in area of rice	%	+
		b) Instability in yield of rice	%	+
		c) Potential loss in rice production	Thousand tonnes	+
3.	Adaptive capacity	a) Growth in area of rice	%	+
		b) Growth in yield of rice	%	+
		c) Area insured in <i>kharif</i>	Thousand ha	+
		d) No. small and marginal farmers insured in <i>kharif</i>	Thousand	+
		e) Proportion of net irrigated area to gross irrigated		+

Table 2 Data source

S.No.	Particular	Period	Source
1.	Daily rainfall in <i>kharif</i>	1990 to 2021	NASA POWER
2.	Area and yield of rice	1990 to 2022	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Department of Agriculture, Government of Maharashtra
3.	Insurance in <i>kharif</i>	2018 to 2022	Pradhan Mantri Fasal Bima Yojna (PMFBY)
4.	Irrigation	1990 to 2002	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

production spanning the years 2011 to 2022 was calculated by using the methodology given by Kumar *et al.* (2016).

Normalization of indicators plays a pivotal role in ensuring the comparability of diverse indicators, particularly when they are measured using different scales. During this normalization process, all indicator values are transformed into a standardized range spanning from 0 to 1.

If the indicators exhibit a positive functional relationship with their respective index, then normalization has been accomplished using the following formula:

$$y_{ij} = \frac{(X_{ij} - \text{Min } X_{ij})}{\text{Max } X_{ij} - \text{Min } X_{ij}}$$

In contrast, when a negative functional relationship is observed, the following formula has been employed for the purpose of normalization:

$$y_{ij} = \frac{(\text{Min } X_{ij} - X_{ij})}{(\text{Max } X_{ij} - \text{Min } X_{ij})}$$

Where, Y_{ij} is the normalized value of j^{th} indicator with respect to i^{th} region ($i = 1, 2, \dots, n$), X_{ij} is the actual value of j^{th} indicator with respect to i^{th} region, $\text{Min } X_{ij}$ and $\text{Max } X_{ij}$ are the minimum and maximum values respectively of j^{th} indicator ($j = 1, 2, \dots, n$) among all the regions

In the current study, principal component analysis (PCA) was employed to extract weights from the data, recognizing its utility for subsequent analyses. Principal Component

Analysis (PCA) stands out as the most widely utilized method and operates under the assumption of linear relationships among variables (Sendhil *et al.*, 2018, Adhav *et al.*, 2021). In this process, we adhered to the Kaiser criterion, which involves selecting principal components with Eigen values surpassing one, indicating their ability to account for the maximum variance in the dataset, as outlined in the following framework,

$$X_t = \sum_{j=1}^r F_j e_t$$

Where, X_t indicates the t -dimensional vector of variables influencing vulnerability, F_j represents the $r \times 1$ common factor, F_t represents the factor loading, e_t represents the associated idiosyncratic error-term of order $N \times 1$

The weights from the PCA were calculated with the following equation,

$$W_i = \frac{L_{ij}^2}{\sum_{j=1}^r L_{ij}^2} E_j$$

Where, W_i represents the weight of the i^{th} variable, E_i represents the Eigen value of the j^{th} factor, L_{ij} represents the loading value of the i^{th} variable on j^{th} factor

The indices for exposure, sensitivity, and adaptive capacity were computed individually by employing their respective indicators in conjunction with the calculated weights. The process was governed by the following equation,

$$\text{Index}_{\text{District}} = \frac{\sum_{i=1}^n X_i W_i}{\sum_{i=1}^n W_i}$$

Where, X_i represents the normalized value of i^{th} variable, W_i is the weight of i^{th} variable

Finally, composite vulnerability index (CVI) was calculated as per the IPCC approach, using the following equation,

$$\text{Vulnerability} = (\text{Exposure} + \text{Sensitivity}) - \text{Adaptive Capacity}$$

In the context of Maharashtra's rice-producing districts, the determination of high, moderate, and low vulnerability levels was accomplished using the composite vulnerability index (CVI). This classification was achieved through the application of mean and standard deviation (SD) norms (Sendhil *et al.*, 2018, Adhav *et al.*, 2021). The classification criteria are outlined as follows:

$$\text{High} = \text{Index} > (\text{Mean} + 0.5 \text{ SD})$$

$$\text{Moderate} = (\text{Mean} - 0.5 \text{ SD}) < \text{Index} < (\text{Mean} + 0.5 \text{ SD})$$

$$\text{Low} = \text{Index} < (\text{Mean} - 0.5 \text{ SD})$$

RESULTS AND DISCUSSION

Table 3 Climate change exposure, sensitivity, adaptive capacity and composite vulnerability index across rice producing districts of Maharashtra

Districts	Exposure Index	Sensitivity Index	Adaptive Capacity Index	Composite Vulnerability Index
Vidarbha				
Bhandara	0.38	0.64	0.76	0.26
Chandrapur	0.38	0.68	0.41	0.65
Gadchiroli	0.44	0.40	0.43	0.41
Nagpur	0.34	0.62	0.55	0.42
Khandesh				
Nashik	0.42	0.66	0.84	0.24
Western Maharashtra				
Kolhapur	0.40	0.17	0.23	0.34
Pune	0.30	0.61	0.38	0.54
Konkan				
Raigad	0.50	0.18	0.15	0.53
Ratnagiri	0.54	0.02	0.12	0.44
Sindhudurg	0.48	0.15	0.23	0.40
Thane	0.44	0.22	0.34	0.32

Exposure index

The analysis of rice-growing districts in Maharashtra which are exposed to various meteorological variables from June to October (the *kharif* season) is summarized in Table 3. It is evident from table 3 that, the selected districts have average exposure index of 0.42, with a standard deviation of 0.07. Notably, Ratnagiri emerges as the most exposed district to climate change, boasting an index of 0.54, primarily due to a sharp decline in rainfall and an increased frequency of heavy rainfall events. Similarly, Raigad and Sindhudurg also display high levels of exposure, with indices exceeding 0.46. Districts such as Gadchiroli, Thane, Nashik, and Kolhapur fall into the category of moderately exposed, with indices ranging from 0.39 to 0.46. On the other hand, Pune exhibits the lowest exposure to climate change, with an index value of 0.30, followed by Nagpur, Chandrapur, and Bhandara, all with indices below 0.39. The regional analysis

underscores that many districts in the Konkan region and Nashik district in the Khandesh region of Maharashtra face significant exposure to erratic rainfall patterns, an increased occurrence of heavy rainfall, and occasional meteorological droughts. However, it is worthy noticing that the disparity in exposure indices (difference between maximum index value and minimum index value) among districts is relatively narrow (0.24), indicating that most regions experience similar exposure to the selected meteorological indicators.

Sensitivity index

Sensitivity levels across the districts were assessed by analyzing factors such as instability in rice area and yield, as well as potential losses in rice production, as outlined in Table 3. Overall, the data reveals that the average sensitivity index for the selected districts was 0.40, with a standard deviation of 0.25. Notably, Chandrapur stands out as the most sensitive district to climate change due to its significant potential loss in rice production, boasting a high index of 0.68. Following closely are Nashik, Bhandara, Nagpur, and Pune, all with indices exceeding 0.52. Surprisingly, Gadchiroli is the sole district categorized as moderately sensitive, with an index ranging from 0.27 to 0.52. Conversely, Ratnagiri demonstrates the lowest sensitivity to climate change, with an index of 0.02, followed by Sindhudurg, Kolhapur, Raigad, and Thane, all with indices below 0.27. Notably, Nashik district in the Khandesh region, as well as most districts in the Vidarbha region, exhibit high to moderate sensitivity, likely due to moderate yield fluctuations and substantial potential losses in rice production. Furthermore, Nashik district, identified as highly sensitive, also shows moderate exposure to climate change, indicating the need for targeted measures to mitigate both exposure and sensitivity in this district. A significant sensitivity gap (difference between maximum index value and minimum index value) of 0.66 underscores evident regional disparities in sensitivity indices across the districts.

Adaptive Capacity Index

In the context of assessing the adaptive capacity of rice-growing districts, the mean adaptive capacity index was calculated at 0.40, with a standard deviation of 0.23. A closer

examination of Table 3 reveals that Nashik stands out as the district with the highest adaptive capacity when it comes to climate change, boasting an impressive index of 0.84. This strong performance can be attributed to factors such as extensive insurance coverage during the *kharif* season, a substantial number of small and marginal farmers with insurance, robust growth rates in both rice area and yield, and a significant proportion of net irrigated area relative to gross irrigated area. Similarly, Bhandara and Nagpur also demonstrate notable adaptive capacity, with indices exceeding 0.52. Conversely, districts like Gadchiroli, Chandrapur, Pune, and Thane exhibit a moderate level of adaptive capacity, with indices ranging from 0.29 to 0.52. In contrast, Ratnagiri displays the lowest adaptive capacity to climate change, with an index of 0.12. Additional districts are classified as having low adaptive capacity in terms of vulnerability, including Raigad, Sindhudurg and Kolhapur, with indices below 0.29. Interestingly, Nashik district in the Khandesh region, as well as most districts in the Vidarbha region, are categorized as having high to moderate adaptive capacity, indicating positive factors such as rapid growth in rice area and yield, extensive insurance coverage, a high presence of small and marginal farmers with insurance, and a substantial proportion of net irrigated area relative to gross irrigated area. Nonetheless, the considerable divergence of 0.72 between the highest and lowest adaptive capacity indices underscores significant inequality among rice-growing districts in terms of their capacity to adapt to climate change.

Composite Vulnerability Index

The composite vulnerability, which considers sensitivity, adaptive capacity, and exposure, reveals substantial disparities in the magnitude of these interconnected indices. This diversity in inter-index values is depicted in Table 3 offers an overview of the index magnitudes. Interestingly, in certain districts like Bhandara and Nashik, the adaptive capacity index surpasses both sensitivity and exposure indices. Conversely, districts such as Chandrapur, Nagpur, and Pune exhibit higher sensitivity indices compared to the other indicators of vulnerability. Meanwhile, districts like Gadchiroli, Kolhapur, Raigad, Ratnagiri,

Sindhudurg, and Thane demonstrate exposure indices higher than the other two indices.

The composite vulnerability index (CVI) is computed by subtracting the adaptive capacity index from sum of exposure and sensitivity, revealing a notable divergence of 0.41 in CVI magnitude, with an average index of 0.41 and a standard deviation of 0.12. District-wise vulnerability estimates in the context of climate change are presented in Table 3. Chandrapur emerges as the most vulnerable district for rice cultivation, with a 0.65 index value. Furthermore, Pune and Raigad fall into the highly vulnerable category, sporting indices exceeding 0.48. Districts like Ratnagiri, Nagpur, Gadchiroli, and Sindhudurg exhibit moderate vulnerability to climate change, with index values ranging between 0.35 and 0.48. In contrast, Nashik is identified as the least vulnerable district to climate change, with an index value of 0.24, followed by Bhandara, Thane, and Kolhapur, all registering indices below 0.35. It's noteworthy that the vulnerability categories vary among districts in different regions of Maharashtra, indicating that not all districts face the same level of vulnerability to climate change. Regions with high vulnerability are marked by elevated exposure and sensitivity to climate change, combined with limited adaptive capacity to mitigate its adverse effects, while districts with robust adaptive capacity to counteract the combined impact of exposure and sensitivity are categorized as less vulnerable.

The varying levels of vulnerability observed among districts across different regions in Maharashtra underscore the crucial necessity for the state to prioritize region-specific research investments aimed to develop climate-resilient rice varieties that can thrive under changing environmental conditions. This includes developing drought-resistant, flood-tolerant, and heat-resistant rice strains adapted to the local climate. Improve irrigation systems and water management infrastructure to ensure consistent and efficient water supply for rice cultivation. Invest in building the knowledge and skills of local farmers through training and extension services. Promote sustainable farming practices that take into account climate change mitigation and

adaptation strategies. Develop and maintain weather monitoring systems and early warning mechanisms to help farmers prepare for extreme weather events, such as floods or droughts. Ensure that farmers have access to credit and insurance schemes to help them manage risks associated with climate-related crop losses. Support the development of community-based resilience initiatives that can help communities respond to and recover from climate-related challenges.

Conclusions

This study's primary focus is to evaluate the vulnerability of rice-producing districts in Maharashtra to climate change by taking into account sensitivity, exposure, and adaptive capacity. The ultimate goal is to provide policymakers with guidance on prioritizing strategies for managing climate change and its variability. Vulnerability arises from notable fluctuations in both cultivated land area and crop yields, resulting in potential losses—a consequence of limited adaptive capacity in regions facing potential impacts due to sensitivity and exposure factors. The variation in vulnerability levels among districts in Maharashtra emphasizes the significance of the state's targeted investment in region-specific research for developing climate-resilient rice varieties, enhancing irrigation and water management, educating local farmers, promoting sustainable farming practices, establishing weather monitoring and early warning systems, providing access to financial support, and supporting community-based resilience initiatives to effectively address the challenges posed by climate change.

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SYNTHESIS AND CHARACTERIZATION OF MYCOGENIC ZINC OXIDE NANOPARTICLES (ZNNP) FOR MANAGEMENT WHITE GRUB (*HOLOTRICHIA SPP.*)

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Abstract

White grubs, significant pests of economic crops, cause extensive damage by feeding on plant roots, leading to yield losses in crops such as sugarcane, maize, and groundnuts. Traditional control methods, including mechanical, chemical, and biological approaches, have limitations in efficacy and environmental safety. This study explores the larvicidal potential of mycogenic zinc oxide nanoparticles (ZnONPs) synthesized using fungal species *Fusarium pallidoroseum*. Surveys conducted in Western Uttar Pradesh identified high white grub infestations, particularly of *Holotrichia serrata* and *H. consanguinea*. Nanoparticles were characterized using UV-Vis spectroscopy, Field Emission Scanning Electron Microscopy (FESEM), Energy Dispersive X-ray Spectroscopy (EDX), and Fourier Transform Infrared Spectroscopy (FTIR). The synthesized ZnONPs demonstrated effective larvicidal activity against white grubs, offering a promising eco-friendly alternative to conventional chemical pesticides. Future research should focus on enhancing nanoparticle stability, understanding molecular interactions, and assessing environmental impacts to optimize their use in integrated pest management.

Keywords: White grubs, Zinc oxide nanoparticles (ZnONPs), Larvicidal activity, Pest management, Eco-friendly pesticides, Nanotechnology, Crop protection.

Introduction

White grubs, also known as root grubs, are significant soil-inhabiting pests affecting a wide range of economic crops by feeding on their roots. These pests belong to the Scarabaeidae family within the order Coleoptera. The most common species include *Holotrichia consanguinea*, *H. serrata*, *H. longipennis*, and *H. fregei*. *H. consanguinea* and *H. serrata* are particularly abundant and pose serious threats to crops (Cock 2013). These are prevalent in various regions of India. The species *H. consanguinea* predominates in Uttar Pradesh, Rajasthan, Gujarat, Haryana,

Punjab, and Bihar. In contrast, *H. serrata* is commonly found in Karnataka, Andhra Pradesh, Tamil Nadu, and Maharashtra, with its spread extending to western and peninsular India (Kulkarni et al., 2009). White grubs have a broad host range, attacking crops such as sugarcane, groundnut, guava, coconut, tobacco, potato, and numerous other oilseeds, pulses, and vegetables. The damage caused by grubs includes wilting and drying up of plants due to root damage, which leads to significant yield losses. Notably, crops like sugarcane, maize, groundnut, and soybean are highly susceptible to white grub infestation (Sreedevi et al., 2019).

White grubs are active throughout the year in soil but are particularly noticeable during the rainy season when adults emerge for mating. These pests thrive in mild clay soils with good aeration, moisture, and temperatures between 20 to 25°C. High soil moisture can be detrimental, and temperatures below 10°C are unfavorable for their survival (Kajuga et al., 2018). The life cycle involves several stages: egg, larval, pupal, and adult. Each species has different durations for these stages, influencing their overall life span. For instance, *H. consanguinea* has a life cycle duration of 76-96 days, while *H. longipennis* can take up to 330 days (Theurkar et al., 2012). The most significant damage caused by white grubs occurs during the second and third larval stages. Infested plants exhibit wilting and can die off, leading to substantial yield losses. In India, white grub infestations cause major crop losses, particularly in sugarcane, with some regions experiencing up to 100% loss in yield (Sreedevi and Tyagi, 2015). Other crops like potato, rice, maize, and groundnut also suffer considerable yield reductions due to these pests.

Several methods are employed to control white grub infestations: 1) Mechanical Methods: These include light traps and twig traps, which attract and kill adult beetles. However, these methods are not effective against larvae (Pandey et al., 2022); 2) Chemical Methods: Chemical pesticides like carbaryl and chlorpyrifos are widely used. However, many such chemicals are banned due to their toxic effects on humans and the environment. Safer options like quinalphos and carbofuran are currently in use (Anaduaka et al., 2023). 3) Biological Methods: Biological control includes the use of biopesticides and entomopathogenic microorganisms.

Fungal biopesticides, such as those based on *Metarhizium anisopliae* and *Beauveria bassiana*, have shown effectiveness against white grub infestations (Bihal et al., 2023). The use of entomopathogenic fungi like *Metarhizium anisopliae* and *Beauveria bassiana* offers an eco-friendly alternative to chemical pesticides. These fungi have been used successfully to control white grubs, although challenges like host specificity and environmental dependency limit their broader application (Vega et al., 2009).

Nanotechnology is emerging as a promising field in agricultural pest management. Nanoparticles, due to their small size and unique properties, offer potential as insecticides. Various nanoparticles (NPs) such as silver (AgNPs), zinc oxide (ZnO NPs), and titanium dioxide (TiO₂ NPs) are being explored for their efficacy against pests (Sahayaraj, 2014).

Myconanoparticles are synthesized by using fungi, providing a novel and eco-friendly approach to nanoparticle production. Fungi are particularly effective in synthesizing zinc nanoparticles, which have shown potential as biopesticides against white grubs (Loshchinina et al., 2022).

Methodology

Collection of white grubs: A survey was conducted in four districts of Western Uttar Pradesh (Meerut, Muzaffarnagar, Bijnor, and Ghaziabad) to assess white grub infestation and collect different strains. In each district, five villages were selected. The Compact Method (CM) by Jordan et al. (2012), with modifications, was employed to sample white grubs during the spring (March-April) and autumn (September-October) seasons over two years (2018 and 2019). Holes measuring 8 inches square and 10 inches deep were dug randomly in fields, and the soil was examined for white grubs. The average number of grubs per hole was recorded. The Action Threshold (AT) for grub infestation was set at 1.6 or more grubs per sample in autumn and 1.04 or more grubs per sample in spring. White grub specimens were preserved under laboratory conditions for further studies.

Synthesis and characterization of Zinc myco-nanoparticles:

Fusarium pallidroseum was used for synthesis of zinc oxide nanoparticles (ZnONPs). The synthesis method of Sagar and Ashok (2012) was followed, with modifications. Fungal biomass (1 g wet biomass weight) was mixed with 100 ml precursor solutions (zinc sulfate) and incubated at room temperature.

A shaking at 150 rpm was maintained. After synthesis, nanoparticles were filtered for further use. Preliminary characterization of synthesized nanoparticles was done using UV-Visible Spectrophotometry, with samples taken at various

time intervals to record absorption spectra. Additional characterizations for concentration, shape, and size were performed using advanced techniques facilitated by different laboratories, such as Field Emission Scanning Electron Microscopy (FESEM), Energy Dispersive X-ray Spectroscopy (EDX), and Fourier Transform Infrared Spectroscopy (FTIR).

Larvicidal Activity:

ZnONPs concentrations were prepared to establish the lethal dosage (LD₅₀) for white grub (second instar larvae). The larvae were exposed to various concentrations of nanoparticles. Ten larvae were taken in three replicates for each concentration. The mortality rate was observed over 96 hours. LD₅₀ values were calculated using Probit analysis and validated by a chi-square test at a 0.05 significance level.

Results and Discussion

Survey and Collection of White Grubs:

A compact method sampling was conducted across various villages in Meerut, Muzaffarnagar, Ghaziabad, and Bijnor. Some locations of Meerut and Ghaziabad exhibited infestation levels beyond the threshold, while villages from Bijnor district showed moderate soil infestation. These parameters showed no significant correlation with the infestation levels. The grubs were preserved in soil from their collection sites and analyzed for morphological characteristics, revealing variations in size and weight across different larval stages. No grubs were found to be naturally infected with entomopathogenic fungi (figure 1).

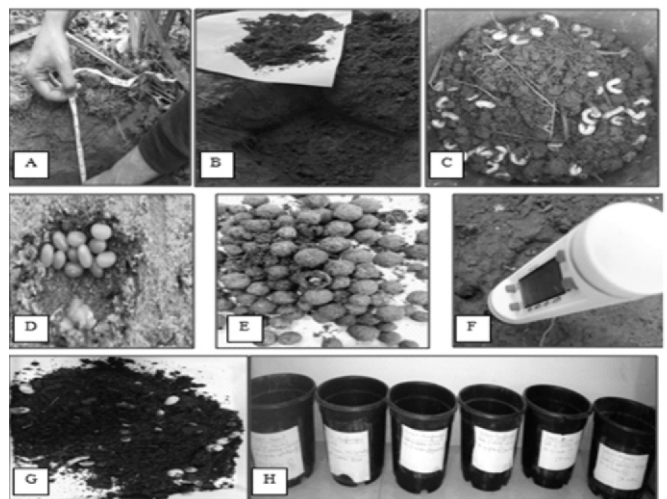


Figure 1: A) Measurement of the square pits for ensuring the desired depth for sampling. B) Soil with white grubs recovered from the square pits. C) Collection of different instars of white grubs in bulk from the surveyed sites. D) The eggs of White grubs found during the survey. E) Earthen balls containing white grubs. F) Measurement of field temperature by TP101 digital soil thermometer. G) White grubs bought to the laboratory and preserved in the pots (H).

Nanoparticle Synthesis and characterization:

The formation of nanoparticles was indicated by colour changes in the reaction mixtures. The test reaction mixture showed mustard yellow colour as compared to the pale yellow colour in control (Figure 2). The intensity of colour change suggested more active nanoparticle synthesis with higher biomass concentrations. The nanoparticles were characterized using UV-Vis spectroscopy, revealing distinct absorption peaks corresponding to ZnONPs (240-380 nm). The optical behaviour of these nanoparticles stabilized after approximately 96 hours (figure 3; table 1). Field Emission Scanning Electron Microscopy (FESEM) was used to analyze the size and morphology of the nanoparticles. The ZnONPs were found to be well-distributed, non-smooth, spherical, and polydispersed, with sizes ranging from 60 nm to 220 nm (figure 4).

Energy Dispersive X-ray (EDX) analysis confirmed the elemental composition of the nanoparticles and also revealed the oxide nature of the synthesized nanoparticle with weight and

atomic percentage of 96.77% and 99.19% respectively (figure 5). Fourier-transform infrared spectroscopy (FTIR) identified various functional groups on the nanoparticle surfaces, which could influence their stability and interactions (figure 6).

Spectral peaks were recorded at 2918.31 cm⁻¹, 1614.94 cm⁻¹, and 1030.37 cm⁻¹ signifying the presence of C-H, C=C, and C-O bonds respectively (ojewska et. al., 2005; Devi and Gayathri, 2010).

Table 1: UV-Vis spectral report of ZnONPs synthesized by *F. pallidorozeum*.

Observation time (hr)	UV-Vis spectrum peak(s) and corresponding absorbance
0	-
4	240 (3.6635), 290 (3.3516), 330 (3.1273), 350 (3.4486)
12	240 (3.0975), 340 (2.4657), 360 (2.5984)
24	340 (2.4264), 360 (2.5481)
48	360 (2.9327)
72	240 (3.383), 290 (3.1118), 340 (2.7889), 360 (2.9112)
96	230 (3.2175), 290 (2.9682), 350 (2.644)
120	240 (3.5072), 340 (2.9147), 400 (3.5686)



Figure 2: The control (left) and test (right) reaction mixtures for

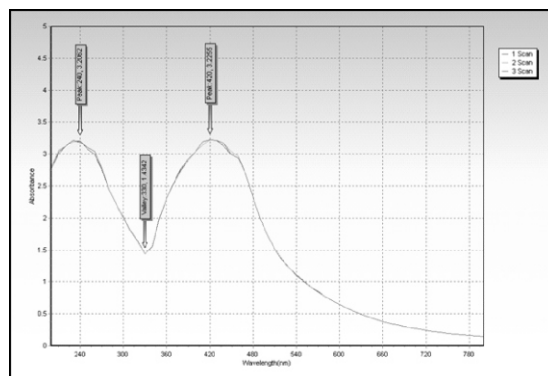


Figure 3: UV-Vis spectral image of ZnONPs recorded after 96 hrs incubation

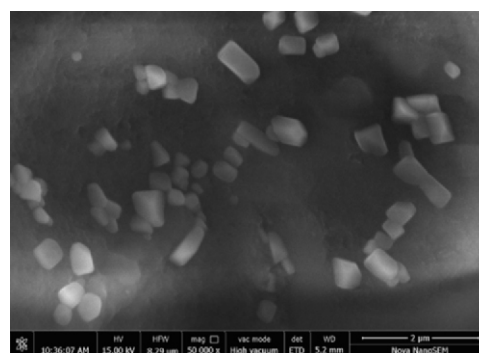


Figure 4: FESEM image of ZnONPs

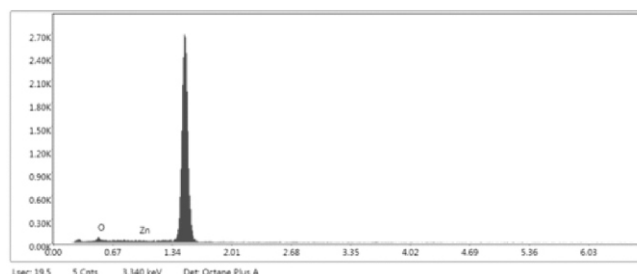


Figure 5: EDX spectral image of ZnONPs.

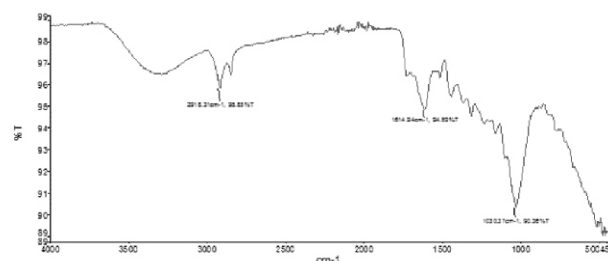


Figure 6: FTIR spectral image of ZnONPs.

LD₅₀ Evaluation and Establishment:

The preliminary tests were conducted to evaluate the impact ZnONPs on white grub larvae. After applying 2 ml of the original concentration all larvae exposed to ZnONPs died within 24

Table 2: Record of second instar larvae died with time in ZnONPs treatments.

Test sample	Replication	Exposure time and mortality counts							Total mortality
		1 hr	4 hrs	12 hrs	24 hrs	48 hrs	72 hrs	96 hrs	
Control	1	-	-	-	-	1	-	-	1
	2	-	-	-	-	-	-	-	0
	3	-	-	-	-	-	-	-	0
25 ppm	1	-	-	-	-	2	1	-	3
	2	-	-	-	-	1	1	-	2
	3	-	-	-	1	1	-	1	3
50 ppm	1	-	-	-	2	1	2	-	5
	2	-	-	-	-	1	2	-	3
	3	-	-	-	1	1	1	1	4
75 ppm	1	-	-	-	3	2	2	1	8
	2	-	-	-	3	4	2	-	9
	3	-	-	-	4	2	3	-	9
100 ppm	1	-	-	-	4	3	3	3	13
	2	-	-	-	3	3	3	2	10
	3	-	-	-	4	3	4	1	12
200 ppm	1	-	-	3	5	3	2	2	15
	2	-	-	4	6	4	2	2	18
	3	-	-	4	4	4	4	2	18

hours. The larvae in the treatment plates showed increased egestion of undigested waste compared to the control plate, suggesting the nanoparticles' stress impact on their digestive processes. The concentrations of ZnONPs were measured at 314.098 ppm using Inductively Coupled Plasma Mass Spectrometry (ICPMS). A series of ppm dilutions were prepared, and the mortality of the second instar larvae was recorded under different concentrations of ZnONPs. The LD₅₀ values was recorded to be 144.34 ppm (table 2).

Discussion

In this study, white grub populations were found to be higher in the autumn than in the spring. This seasonal variation aligns with the behavior of third instar larvae, which burrow deeper into the soil during winter to pupate and later emerge as adult beetles (Pathania et al., 2016; Chavan et al., 2024). Despite similar soil conditions across districts, grub density varied, potentially due to factors like recurring pest populations, crop rotations, and environmental

conditions. The two most common species observed were *Holotrichia serrata* and *H. consanguinea*, which are widely distributed and known as significant pests in various regions of India (Sreedevi and Tyagi, 2015). The biological methods of nanoparticle synthesis, such as by using fungi, are eco-friendly and cost-effective. Fungi have been effective in producing nanoparticles through the reduction of metal salts by extracellular enzymes (Guilger-Casagrande and de Lima, 2019). The synthesized nanoparticles exhibit unique optical properties that are valuable for applications in pest management, as demonstrated by their ability to affect white grub larvae. Metal nanoparticles exhibit unique optical properties that depend on factors such as size, shape, concentration, agglomeration state, and refractive index near their surface. These properties make UV-Vis spectroscopy an essential tool for identifying and characterizing nanoparticles (Amendola and Meneghetti, 2009; Desai et al., 2012). Metal nanoparticles like zinc, gold, and silver interact strongly with specific wavelengths of light, which is foundational to the

field of plasmonics (Yu et al., 2019). The UV-Vis absorption peaks for ZnONPs can vary widely, with reports indicating peaks at 274 nm, 320 nm, 350 nm, 359 nm, and 380 nm (Al-Dhabi and Valan Arasu, 2018; Kalpana et al., 2018; Ezealisiji et al., 2019). Field Emission Scanning Electron Microscopy (FESEM) provides detailed topographical and elemental information at high magnification and resolution, allowing for clear imaging without electrostatic distortion, and is especially useful in nanoparticle analysis due to its high resolution and depth of field (Akhtar, 2018). In this study, FESEM revealed that nanoparticles synthesized with a higher fungal biomass had finer sizes due to increased secretion of extracellular enzymes that enhance the reduction of metal precursors. Energy Dispersive X-ray (EDX) analysis, often coupled with FESEM, helps determine the elemental composition of nanoparticles and detect any contaminants (Scimeca et al., 2018).

Previous studies have also reported that efficacy of nanoparticles against insect larvae of animal and plant pests (Sankar and Abideen et al., 2015; Adesuji et al., 2016; AS and Thangapandiyar, 2019; Shamseldean et al., 2022). The toxicity of these nanoparticles is often measured using Probit Analysis, which is a standard method to evaluate the toxicity levels of chemicals and nanoparticles (Zavitri et al., 2023). The study highlights that nanoparticles, when absorbed or ingested by larvae, generate reactive oxygen species (ROS), causing cellular stress that disrupts the digestive system, leading to increased mortality (Hu and Paliæ, 2020). Inductively Coupled Plasma Mass Spectrometry (ICPMS) is used to accurately measure the concentration of metal nanoparticles in solutions, making it a reliable technique for such studies (Hansen and Clogston, 2024). Research on ZnONPs has mainly focused on their larvicidal properties against animal pests. For example, ZnONPs were effective against *Aedes aegypti* larvae with a significant LC50 value of 34.04 ppm (Al-Dhabi and Valan Arasu, 2018). Other studies have reported the pesticidal efficacy of nanoparticles against food storage pests, demonstrating their potential as a broad-spectrum pest control method (Stadler et al., 2010; Yang et al., 2014; Babu et al., 2014; Malaikozhundan and Vinodhini, 2018). These

findings underscore the versatility and effectiveness of nanoparticles in managing a variety of pest species.

Conclusion

This study confirms the potential of mycogenic zinc oxide nanoparticles as effective larvicidal agents against white grubs, a major pest affecting various economic crops. The nanoparticles synthesized using *Fusarium pallidoroseum* were shown to be highly effective, with specific particle sizes and concentrations resulting in significant mortality rates among white grub larvae. The use of these nanoparticles could reduce reliance on harmful chemical pesticides and provide a safer, more environmentally friendly option for pest management. However, further research is necessary to improve nanoparticle stability, explore the physiological mechanisms involved in pest control, and conduct comprehensive environmental impact assessments. Additionally, on-site trials and risk assessments are required before these nano-formulations can be released commercially. This approach has the potential to revolutionize pest management by reducing chemical pesticide use and mitigating their associated risks to human health and non-target organisms.

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IMPACT OF YEAST ON PHYSIC-CHEMICAL PROPERTIES OF MIXED FRUIT WINE DURING STORAGE

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Abstract

The mixture of fruits pulp containing low sugar and thus sugar level will adjust from 25 °Brix by using sugar solution. The pH level of mixture will adjusted at 4. The juice will yeast by *saccharomyces cerevisiae* with 0.5 %. The TSS largely affects the various physic-chemical parameters of fermented wine. Sugar is the main substrate for fermentation of fruits juice into alcohol. The specific gravity of the wine was found to be decreased with increase in sugar percent. Wine is a cocktail produced using aged grapes or different organic products. Yeast devours the sugar in the grapes and converts it to ethanol and carbon dioxide.

Introduction

Wine is an alcoholic beverage produced from juices of variety of fruits by fermentative action of microorganisms either spontaneously or seeding with a particular strain mainly of yeast species to adopt a particular quality of wine. Wine is one of the most recognizable high value added products from fruits (Okeke *et al.*, 2015). Wines are regular utilization characterized as a result of the typical alcoholic aging of the juice of sound ready grapes. Grape wines are maybe the most monetarily significant organic product juice liquor (Kelebek and Canbas 2013). Non-accessibility and generally significant expense of getting successful financially alcoholic fermentative *Saccharomyces cerevisiae* strains are a significant compel being developed and supporting neighborhood modern maturation measure (Yabaya, *et al.*, 2016). The maturation might be started utilizing a starter culture of *Saccharomyces cerevisiae*, in which case the juice is vaccinated with populace of yeast of 10^6 - 10^7 cfu/ml juice. This methodology produces wine of commonly anticipated taste and quality. On the off chance that the maturation interaction is permitted to continue normally, the yeast present

on the outside of the natural products. The characteristic aging cycle is polished generally around the globe, particularly for home creation of wine. In normal maturation measure, there is a reformist example of yeast development. *Saccharomyces cerevisiae* can endure a lot more elevated levels of ethanol up to 15% v/v or more than different species who just endure up to 5% or 8% liquor. (Adams, 1990; Guleria, 2014 and Aidoo, 1994). Strains of *Saccharomyces cerevisiae* yeast which are known to deliver diverse unpredictable profiles have been regularly utilized for alcoholic maturation.

Materials and Methods

Alcohol Content

Alcohol determination by specific gravity method provides an approximation of the alcohol content only. The method assume that the difference in specific gravity. Before and after fermentation is due solely to the conversion of sugars before fermentation. The alcohol content calculates by the following relation:

$$\text{Alcohol (\%v/v)} = (SG_2 - SG_1) / 0.0074$$

Where,

SG₁ = Initial specific gravity measurement

SG₂ = Final specific gravity measurement

pH Content

The pH was determined directly during fermentation using a digital pH meter as described by Ochai and Kolhatkar (2008).

Total soluble solids (TSS)

The total soluble solid content was determined in terms of °Brix by using hand refractometer at 20 °C. It measures TSS in terms of refractive index. Brix is a measure of solids only in case of pure sucrose solutions. Generally, fruit juices contain more sugar than any other soluble constituents and hence brix provides a useful guide of soluble solid or sugar content (Maziar, 2010).

Specific gravity Content

The specific gravity was determined using specific gravity bottle. The empty bottle was weighed, filled with distilled water and reweighed. It was then filled with sample and weighed (Ranganna, 1986).

The specific gravity, of the sample will be calculated, as follows:

$$\text{Specific gravity} = \frac{W_s}{W_w}$$

Where, W_s = Weight of known volume of sample in gm

W_w = Weight of an equal volume of water in gm
Density Density

The density, $\bar{n}$ in kg/m³, will be calculated as:
= 1000 × Specific gravity

Experimental Plan

The juice will be extract by homogenizing the pulp mixer after washing the fruits. The mixture of fruits pulp containing low sugar and thus sugar level will adjust from 25 °Brix by using sugar solution. The pH level of mixture will adjusted at 4. The juice will yeast by *Saccharomyces cerevisiae* with 0.5%. The complete mixture will be hold 30 days for fermentation at room temperature. The wine will racking pasteurization (60 °C, 3 min.) and bottling after fermentation process.

Fermentation Process

The good quality fruits were procured from the local market of Meerut. The procured fruits were washed with water and unwanted material like

dust; dirt and surface adhering were removed. The fruits were peeled with the help of a stainless steel knife and boot the ends of the fruits were weighted according to the treatments ratio. After setup the treatments of sample the sugar level in juices were adjusted at 25 °Brix and yeast *Sacharomyces cerevisiae* was added to the clarified juice to initiate fermentation for 30 days. The yeast percentages were used in the treatment 0.5 % than the samples were fermented at room temperature. In red wine making the pulp, skins and seeds of grapes and other fruits are kept together after crushing and during all parts of the fermentation. This is done to extract color and flavor. The post fermentation process was necessary to ensure good conservation and presentation of produced mixed fruit wine.

Effect on physico-chemical characteristics of mixed fruits wine with 0.5% yeasting on storage period.

Effect on Specific Gravity

The experimental data are presented in Table 1 the data were analyzed to observe the effect of 0.5% yeasting concentration of mixed fruit wine during storage period as show in bar diagrams Figure 1. The Specific Gravity of mixed fruit wine showed an increasing trend for all the treatments with storage period start from 0, 30, 60 and 90 days. The study revealed that specific gravity of the samples having yeast concentration of 0.5%. Estimation of specific gravity of treatments T₁, T₂, T₃, T₄, T₅ and T₆ has been conducted. It has been studied that as the number of day's increases, the specific gravity also increases gradually. The specific gravity ranges from 1.065 to 1.075 for T₁ on 1st day to last day of storage period. 1.078 was the starting specific gravity of T₂ which increased to 1.089 on 90th day. The initial specific gravity of T₃ was 1.097 which increased to 1.104 on the 90th day. For T₄, the specific gravity starts from 1.099 and increased to 1.106 on 90th day. On the 1st day the specific gravity was 1.099 for T₅ and then it increased to 1.108 on 90th day. In case of T₆, specific gravity was 1.101 on 1st day which increased to 1.111 on 90th day. The ANOVA of steady revealed that the specific gravity of mixed fruit wine was found to be significant at p = 0.05 level of significance.

Table 1 Effect on Specific gravity of 0.5%

yeasting during storage period

Treatment s/Days	0 Day	30 Day	60 Day	90 Day
T ₁	1.065	1.067	1.071	1.075
T ₂	1.078	1.081	1.085	1.089
T ₃	1.097	1.099	1.102	1.104
T ₄	1.099	1.102	1.104	1.106
T ₅	1.099	1.102	1.106	1.108
T ₆	1.101	1.104	1.109	1.111

Effect on Total Soluble Solids (TSS)

The TSS content of mixed fruit wine showed a decreasing trend for all the treatments with storage period up to 30 days. The study revealed that TSS of the samples having 0.5% yeast was observed as 25 °Brix in fresh samples. From Table 2 and Figure 2 it was observed that TSS of all the samples decreased with storage period (0, 30, 60, and 90 days). The TSS largely affects the various physico-chemical parameters of fermented wine. Sugar is the main substrate for fermentation of fruits juice into alcohol. The specific gravity of the wine was found to be decreased with increase in sugar percent. This might be due to increase in alcohol percent with increase in sugar percent. Estimation of TSS of T₁, T₂, T₃, T₄, T₅ and T₆ has been conducted. It has been studied that as the number of day's increases, the TSS (°Brix) also decreases gradually. The TSS (°Brix) ranges from 17.50 to 14.17 for T₁ on 1st day to last day of storage period. 16.83 was the starting TSS (°Brix) of T₂ which decreased to 13.50 on 90th day. The initial TSS (°Brix) of T₃ was 16.50 which decreased to 13.50 on the 90th day. For T₄, the TSS (°Brix) starts from 16.50 and decreased to 13.50 on 90th day. On the 1st day the TSS (°Brix) was 15.67 for T₅ and then it decreased to 12.50 on 90th day. In case of T₆, TSS (°Brix) was 15.50 on 1st day which decreased to 12.50 on 90th day. The ANOVA of steady revealed that the TSS of mixed fruit wine was found to be significant at p = 0.05 level of significance.

Table 2 Effect on TSS of 0.5% yeasting during storage period

Treatments/Days	0 Day	30 Day	60 Day	90 Day
T ₁	17.5	16.5	15.83	14.17
T ₂	16.83	15.83	14.94	13.50

T ₃	16.5	15.5	14.83	13.50
T ₄	16.5	15.5	14.83	13.50
T ₅	15.67	14.83	13.94	12.50
T ₆	15.5	14.8	13.93	12.50

Effect on Density

The Density of mixed fruit wine showed an increasing trend for all the treatments with storage period up to 0, 30, 60 and 90 days. The study revealed that density of the samples having yeast concentration of 0.5%. The experimental data are presented in Table 3. The data were analyzed to observe the effect of 0.5% yeasting concentration of mixed fruit wine during storage period as shown in bar diagrams Figure 3. Estimation of density of T₁, T₂, T₃, T₄, T₅ and T₆ has been conducted. It has been studied that as the number of day's increases, the density also increases gradually. The density ranges from 1065 kg/m³ to 1075 kg/m³ for T₁ on 1st day to last day of storage period. 1078.33 kg/m³ was the starting density of T₂ which increased to 1089 kg/m³ on 90th day. The initial density of T₃ was 1097 kg/m³ which increased to 1104 kg/m³ on the 90th day. For T₄, the density starts from 1099 kg/m³ and increased to 1106 kg/m³ on 90th day. On the 1st day the density was 1099.33 kg/m³ for T₅ and then it increased to 1108 kg/m³ on 90th day. In case of T₆, density was 1101 kg/m³ on 1st day which increased to 1111 kg/m³ on 90th day. The ANOVA of steady revealed that the density of mixed fruit wine was found to be significant at p = 0.05 level of significance.

Effect on Density of 0.5% yeasting during storage period

Treatments/Days	0 Day	30 Day	60 Day	90 Day
T ₁	1065	1067	1070.67	1075
T ₂	1078.33	1081	1085.00	1089
T ₃	1097	1099.33	1101.67	1104
T ₄	1099	1101.67	1104.00	1106
T ₅	1099.33	1102.33	1106.00	1108
T ₆	1101	1103.67	1109.33	1111

Effect on pH content

According to Fleet, pH directly affects wine stability. This may be as a result of the fact that at a pH close to neutral (7.0), most microorganisms such as bacterial and molds including some yeasts become more active for fermentation and subsequent spoilage of wine, while pH below 3.5

eliminates most of the microbes and favors only a few of the microorganisms for fermentation. Molds and yeasts are usually low pH tolerant and are therefore associated with the spoilage of food with low pH. Yeasts can grow in a pH range of 4 – 4.5 and molds can grow from 2 – 8.5 but favor low pH. The pH plays an important role in aging, clarifying or fining. As the strength of the relative charge of suspended particles decreases in the wine, the pH of the wine increases.

At high pH, organic protein fining agents may possess a positive charge insufficient to bind to the negatively charged particulates, thus potentially increasing the turbidity of the wine (Nuengchamnog and Ingkaninan 2017). Estimation of pH content of treatments T₁, T₂, T₃, T₄, T₅ and T₆ has been conducted. It has been studied that as the number of day's increases, the pH content also decreases gradually. The pH content ranges from 3.70 to 3.63 for T₁ on 1st day to last day of storage period. 3.72 was the starting pH content of T₂ which decreased to 3.65 on 90th day. The pH content of T₃ was 3.69 which decreased to 3.62 on the 90th day. For T₄, the pH content starts from 3.68 and decreased to 3.60 on 90th day. On the 1st day the pH content was 3.59 for T₅ and then it decreased to 3.50 on 90th day. In case of T₆, pH content was 3.52 on 1st day which decreased to 3.48 on 90th day. The experimental data are presented in Table 4 The data were analyzed to observe the effect of 1% yeasting concentration of mixed fruit wine during storage period as show in bar diagrams Figure 4. The ANOVA of steady revealed that the pH content of mixed fruit wine was found to be significant at p = 0.05 level of significance.

Effect on pH content of 0.5% yeast during storage period

Treatment s/Days	0 Day	30 Day	60 Day
T ₁	3.70	3.68	3.66
T ₂	3.72	3.69	3.67
T ₃	3.69	3.66	3.62
T ₄	3.68	3.65	3.60
T ₅	3.59	3.56	3.50
T ₆	3.52	3.51	3.48

Effect on Alcohol Content

The alcohol content production of mixed fruit wine showed an increasing trend for all the

treatments with storage period up to 90 days. The experimental data are presented in Table 5 The data were analyzed to observe the effect of 1% yeasting concentration of mixed fruit wine during storage period as show in bar diagrams Figure 5 Estimation of alcohol content of treatments T₁, T₂, T₃, T₄, T₅ and T₆ has been conducted. It has been studied that as the number of day's increases, the alcohol content also increases gradually. The alcohol content ranges from 6.80 to 8.78 for T₁ on 1st day to last day of storage period. 8.96 was the starting alcohol content of T₂ which increased to 10.36 on 90th day. The initial alcohol content of T₃ was 10.14 which increased to 11.31 on the 90th day. For T₄, the alcohol content starts from 10.36 and increased to 11.58 on 90th day. On the 1st day the alcohol content was 10.95 for T₅ and then it increased to 11.89 on 90th day. In case of T₆, alcohol content was 12.30 on 1st day which increased to 13.47 on 90th day. The ANOVA of steady revealed that the alcohol content of mixed fruit wine was found to be significant at p = 0.05 level of significance.

Table 5 Effect on Alcohol Content of 0.5% yeasting during storage period

Treatment s/Days	0 Day	30 Day	60 Day	90 Day
T ₁	6.80	7.42	8.20	8.78
T ₂	8.96	9.32	9.86	10.36
T ₃	10.14	10.59	11.04	11.31
T ₄	10.36	10.72	11.35	11.58
T ₅	10.95	11.26	11.58	11.89
T ₆	12.30	12.70	13.20	13.47

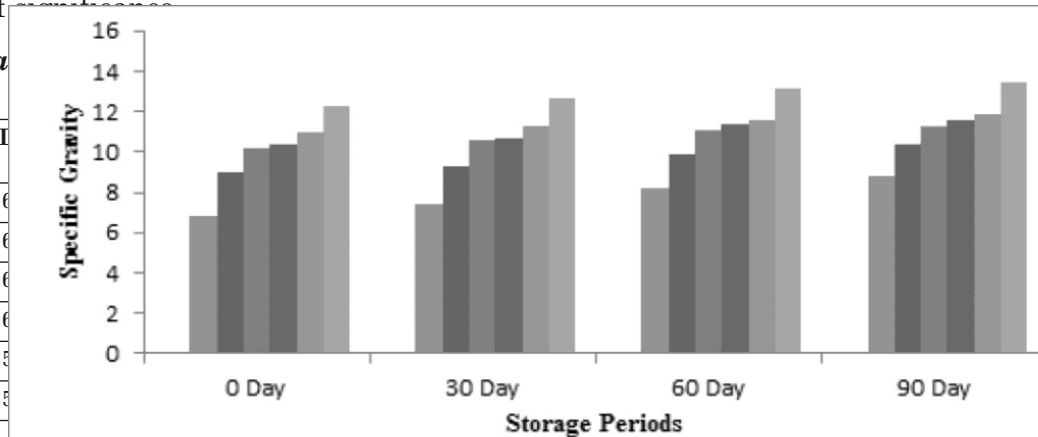


Fig. 1 Effect on Specific gravity of 0.5% yeasting during storage period

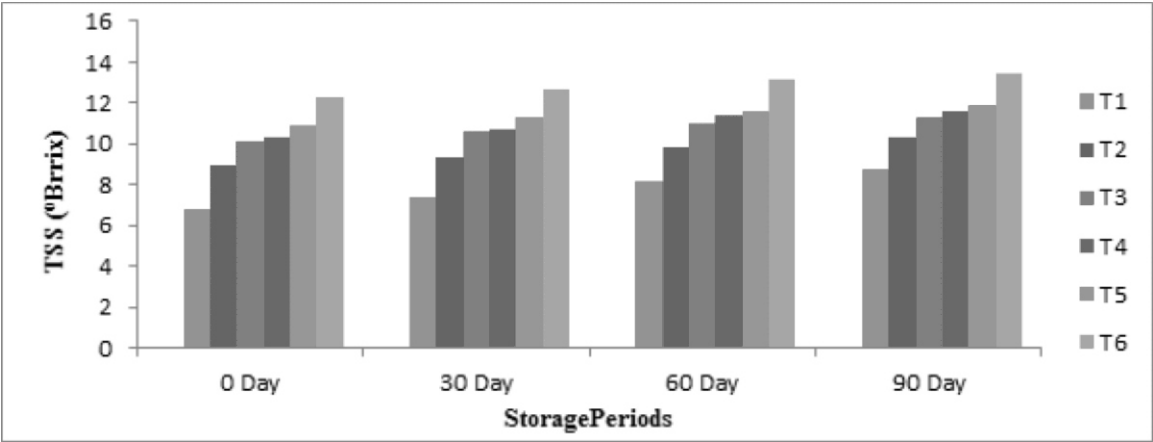


Fig. 2 Effect on TSS of 0.5% yeasting during storage period

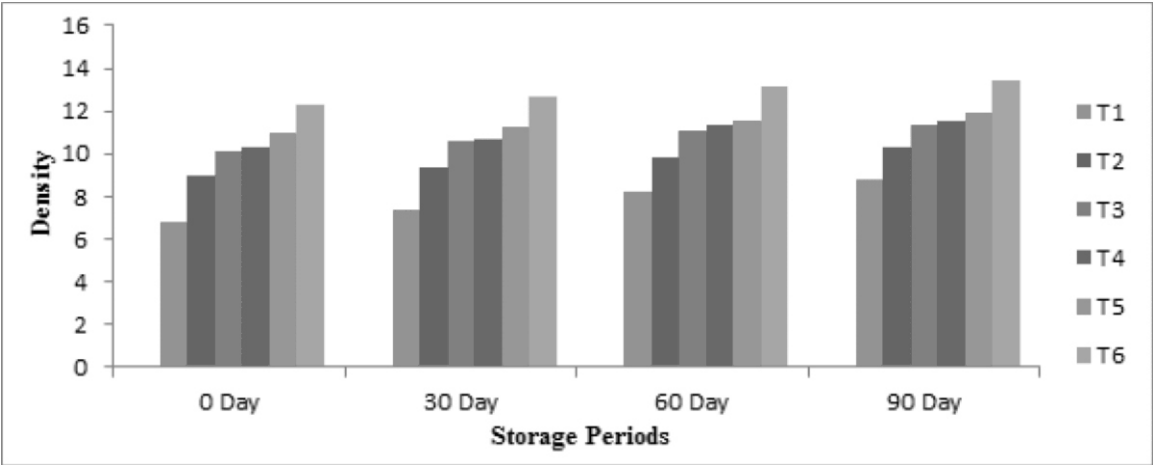


Fig. 3 Effect on Density of 0.5% yeasting during storage period

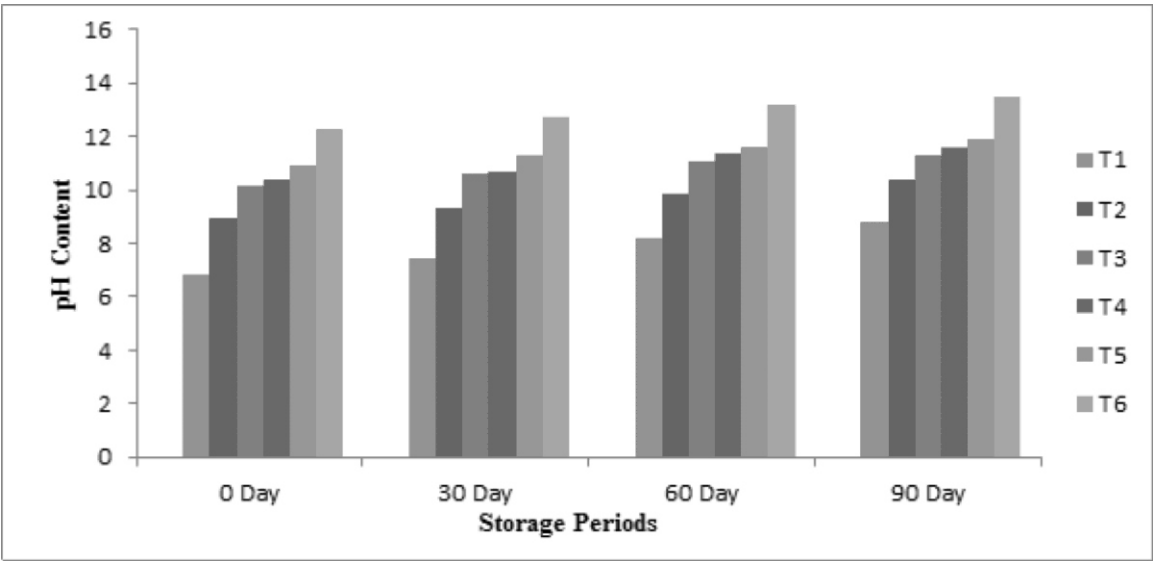


Fig. 4 Effect on pH content of 0.5% yeasting during storage period

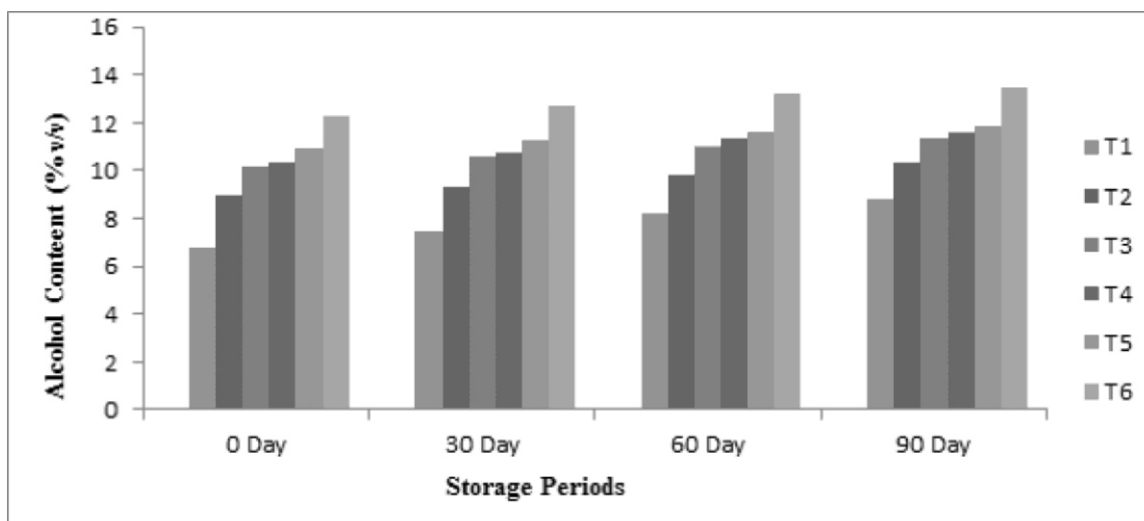


Fig. 5 Effect on Alcohol Content of 0.5% yeasting during storage period

Conclusion

Wine is any alcoholic beverage produced from juices of variety of fruits by fermentative action of microorganisms either spontaneously or seeding with a particular strain mainly of yeast species to adopt a particular quality of wine. Wine is one of the most recognizable high value added products from fruits. Most commercially produced wines are usually made from fermented grapes; this fermentation process is not done by introducing any chemicals or sugar but by adding different species of yeast to the crushed grapes. Yeast has the capability of converting grapes into an alcoholic compound and removing the sugar content in it for the production of different types of wines. The nutritive value of wine is increased due to release of amino acids and other nutrients from yeast during fermentation. We noted high fermentation activity of the yeast which to complete the fermentation after 30 days. Increase in sugar concentration also increases the acidity of wine. Inoculum % has very less effect on physicochemical parameters of fermented juice. The wine has been produced by a technology similar to that of traditional wine production. As the demand for wine there is also a requirement for experts who can create the good quality wine. Little work has been reported on development and quality assessment of mixed fruits wine developed from mixed fruits incorporating grapes, orange, pineapple and banana fruits. Thus, there is a need to develop the mixed fruits red wine which would serve as nutritious products. In this sequence, this study was conducted to developed mixed fruits wine (Kumar, *et al.*, 2021).

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BIOFORTIFICATION STRATEGIES TO ENHANCE NUTRIENT CONTENT IN CROPS

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Abstract

A sustainable way to combat hunger is biofortification, which entails using genetic engineering or traditional breeding to increase the nutritional content of basic crops. The importance of biofortification in preventing world hunger is covered in this abstract, along with a summary of the methods used to enrich crops with vital nutrients. The efficacy of several biofortification techniques, such as traditional breeding, transgenic approaches and agronomic practices, in raising the concentrations of essential elements like iron, zinc, vitamin A and vitamin C in staple crops including rice, wheat, maize, and cassava is being investigated. This abstract highlights the success stories of biofortified crops, such as iron and zinc-enriched beans, vitamin A-rich rice, and selenium-fortified wheat. These crops have demonstrated the potential to contribute significantly to alleviating nutrient deficiencies, especially in regions where traditional diets lack essential micronutrients. It also highlights the necessity of multidisciplinary cooperation between farmers, policymakers, nutritionists, breeders, and plant scientists in order to enhance global public health outcomes and hasten the adoption of biofortified crops. Biofortification stands as a promising avenue for enhancing crop nutrient content and addressing global malnutrition challenges. Continued research, investment, and collaboration are crucial to advancing biofortification strategies and realizing their potential to improve the nutritional status of populations worldwide.

Keywords: Traditional breeding, Transgenic approaches, Agronomy practices

Introduction

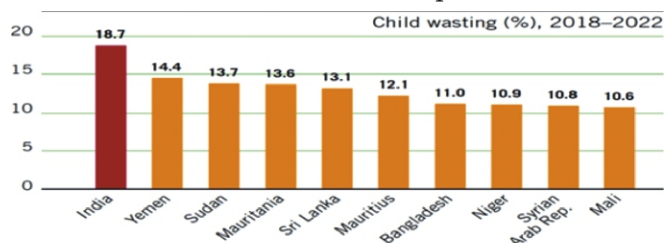
Biofortification, the process of breeding nutrients into food crops, provides a comparatively cost effective, sustainable, and long-term means of delivering more micronutrients. This approach not only will lower the number of severely malnourished people who require treatment by complementary interventions but also will help them maintain improved nutritional status. Moreover, biofortification provides a feasible means of reaching malnourished rural populations who may have limited access to commercially marketed fortified foods and supplements (Potrykus I. 1999). The biofortification strategy seeks to put the micronutrient-dense trait in those varieties that already have preferred agronomic

and consumption traits, such as high yield. Marketed surpluses of these crops may make their way into retail outlets, reaching consumers in first rural and then urban areas, in contrast to complementary interventions, such as fortification and supplementation, that begin in urban centers. Biofortified staple foods cannot deliver as high a level of minerals and vitamins per day as supplements or industrially fortified foods, but they can help by increasing the daily adequacy of micronutrient intakes among individuals throughout the life cycle (Bouis et al. 2011).

1.1 Status of malnutrition

Malnutrition contributes to increased morbidity, disability, stunted mental and physical growth, and reduced national socio-economic

development. The extent of malnutrition worldwide as well as in India is presented below



Source: Global Hunger Index 2023

Malnutrition contributes to loss of 11% GDP in Asia and Africa. Malnutrition in all its forms could cost society up to US\$3.5 trillion per year.

2. Biofortification Approaches

2.1 Plant Breeding

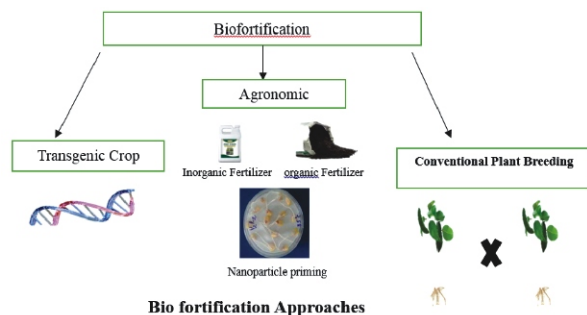
Plant breeding programs focus on improving the level and bioavailability of minerals in staple crops using their natural genetic variation (**Welch and Graham 2005**). Breeding approaches include the discovery of genetic variation affecting heritable mineral traits, checking their stability under different conditions, and the feasibility of breeding for increasing mineral content in edible tissues without affecting yields or other quality traits. Breeding for increased mineral levels has several advantages over conventional interventions (e.g., sustainability); no high mineral varieties produced by this method have been introduced onto the market thus far. This reflects long development times, particularly if the mineral trait needs to be introgressed from a wild relative. Breeders utilize molecular biology techniques such as quantitative trait locus (QTL) maps and marker-assisted selection (MAS) to accelerate the identification of high-mineral varieties, but they have to take into account differences in soil properties (e.g., pH, organic composition) that may interfere with mineral uptake and accumulation. For example, the mineral pool available to plant roots may be extremely low in dry, alkaline soils with a low organic content (**Cakmak 2008**).

2.2 Conventional Plant Breeding

This allows crop scientists to make significant improvement in the nutritional, eating quality, and agronomic traits of major subsistence food crops. Conventional breeding is limited, however,

because it can only use the genetic variability already available and observable in the crop being improved or occasionally in the wild varieties that can cross with the crop. Furthermore, conventional breeders usually have to trade away yield and sometimes grain quality to obtain higher levels of nutrition. One example is quality protein maize (QPM), which has taken decades of conventional plant breeding work to develop into varieties acceptable to farmers. However, multiple gains are at times possible, as with iron and zinc in rice and wheat, where the characteristics that lead to more iron and zinc in the plant can also lead, by some accounts, to higher yield. Other biofortified crops, such as the orange-fleshed sweet potatoes (OFSP) promoted through the HarvestPlus program in Africa, have been successfully selected and developed for both nutrient and (at least rainy season) yield traits (**Unnevehr et al. 2007**).

Mutation Breeding Mutation breeding has been used extensively in developed and developing countries to develop grain varieties with improved grain quality and in some cases higher yield and other traits. This technique makes use of the greater genetic variability that can be created by inducing mutations with chemical treatments or irradiation. The FAO/International Atomic Energy Agency (IAEA) website contains more than 2500 varieties that have been developed through mutation breeding (Mutant varieties database). Of these, 1568 are in Asia, 695 in Europe, and 165 in the United States. Most of the European and US mutants are flowers, but most in Asia are basic food crops such as wheat, rice, maize, and soybeans. According to their website, FAO/IAEA include biofortification as one of the objectives of their mutagenesis program, but there do not seem to be any applicable results yet. Varieties produced using mutagenesis can be grown and certified as organic crops in the United States, whereas transgenic crops developed using recombinant DNA (rDNA) technology cannot.



2.3. Molecular Breeding

Also called marker-assisted breeding, this is a powerful tool of modern biotechnology that encounters little cultural or regulatory resistance and has been embraced so far even by organic growers because it relies on biological breeding processes rather than engineered gene insertions to change the DNA of plants. This technique is expanding rapidly with the development of genomics, which is the study of the location and function of genes, and with the rapid decline in costs of screening plant tissue. Once scientists have identified the location of a gene for a desirable trait, they build a probe that attaches itself only to a DNA fragment, a so-called marker, unique to that gene. They then can use this marker as a way to monitor and speed up their efforts to move this trait into relatives of the plant using conventional breeding. For example, since the marker can be detected in the tissue of new seedlings, the presence or absence of the desired trait can be determined without having to wait for a plant to mature, often reducing by years the length of a typical crop development process. If molecular breeding reduces the number of generations required to develop a pure line variety by three generations, this can save 3 years of research time. The use of molecular breeding has increased dramatically both by private seed companies and government plant breeders in developed countries, and it is gradually spreading to developing countries (Pray 2006). Using this technique, plant breeders also can stack into one variety several different genes that code for different traits, for example, QPM, disease resistance, and drought tolerance in maize (Pray 2006). This technique has also been used to find recessive traits in plants that cannot be located by conventional breeding or other techniques.

2.4. Genetic Engineering

Genetic engineering is the latest weapon in the armory against mineral deficiency and uses advanced biotechnology techniques to introduce genes directly into breeding varieties. The genes can come from any source (including animals and microbes) and are designed to achieve one or more of the following goals (Zhu *et al.* 2007):

- (a) improve the efficiency with which minerals are mobilized in the soil,
- (b) reduce the level of antinutritional compounds,
- (c) increase the level of nutritional enhancer compounds such as inulin.

Genetic engineering, or rDNA, is a technique that offers still greater speed and reach because it moves specific genes with desired traits from a source organism—one which does not have to be a related organism—directly into the living DNA of a target organism. The transgenic trait is added without normal biological reproduction, but once in the plant it becomes inheritable through normal reproduction. GE was necessary for the development of golden rice, which contains the precursor to VA from a daffodil plant. This was a trait missing from rice plants, and it could not be introduced conventionally since daffodils cannot be crossed with rice plants. Molecular breeding and GE also have advantages over traditional breeding because they make it easier to develop crops with multiple desired nutritional traits, maintain agronomic viability of biofortified crops, adapt agriculture improvements arising in the United States for obscure crops in developing countries, etc.

2.5. Microbiological Interventions

2.5.1. Plant Growth Promoting Rhizobacteria

These include beneficial bacteria that colonize plant roots and enhance plant growth by a wide variety of mechanisms. The use of PGPR is steadily increasing in agriculture, as it offers an attractive way to reduce the use of chemical fertilizers, pesticides, and related agrochemicals (Rana *et al.* 2012). Interventions using PGPR or other biological agents are limited. Secretion of phytosiderophores by microorganisms and plants in restricted spatial and temporal windows represents an efficient strategy for uptake of iron

and other micronutrients by plants from the rhizosphere. Analysis of the complex interactions between soils, plants, and microbes. In relation with micronutrient dynamics represents a unique opportunity to enhance our knowledge of the rhizosphere ecology. Such progress can provide information and tools enabling us to develop strategies to improve plant nutrition and health with decrease in the application of chemical inputs. Microorganisms are known to differ significantly in competing with higher plants for micronutrients. Microorganisms differ in competing with higher plants for micronutrients. Species of *Azotobacter* differed in their competitiveness with wheat plants in extracting Fe and Zn (**Shivay *et al.* 2010**). Biofortification of crops through application of PGPR can be therefore considered as a possible supplementary measure, which along with breeding varieties can lead to increased micronutrient concentrations in wheat crop, besides improving yield and soil fertility.

2.5.2. AM Fungi

These symbiotic fungi, therefore, change, directly or indirectly, the mineral nutrition of plant products that are also essential for humans. However, the role of mycorrhizas on element biofortification may be piloted through agricultural practices. the extensive AM mycelial systems (the vegetative parts of the fungus) effectively explore soil substrates and acquire soil inorganic nutrients, including major macronutrients N, P, and K and micronutrients Cu, Fe, and Zn, with some capacity for acquiring organic N and P.

2.5.3. Agronomic Intervention

The agronomic strategy of biofortification is mainly based on the application of mineral fertilizers, particularly Fe and Zn, in order to increase the solubility and mineral content of micronutrients in the soil (**White and Broadley 2009**). The effective and proven role of Zn in boosting the human immune system against viruses and other health threats may be a good reason to grow wheat and rice varieties with high Zn content. It was reported in the studies that these micronutrient deficiencies in the soil can be eliminated by the fertilization method. An

increase in micronutrient concentration and grain yield was reported in areas with micronutrient deficiencies after the application of fertilizer and micronutrient combination to soils and leaves (**Cakmak *et al.* 2010a; Imtiaz *et al.* 2010**). For example, in countries such as Australia, the USA, Canada, and in the European region which have different climate characteristics and micronutrient deficiencies in the soils, fertilizers and micronutrients are applied to the soil to increase the grain crop yield and fruit yield in trees. The effective and proven role of Zn in boosting the human immune system against viruses and other health threats may be a good reason to grow wheat and rice varieties with high Zn content. Fe and Zn fertilization is one of the methods to increase the accumulation and yield of minerals in grains (**Alloway 2008**). It was determined in the studies that the amount of Zn and Fe increases in Fe- and Zn-applied wheat, rice, and corn (**Aref 2010; Stomph *et al.* 2011**).

2.6. Biofortification Through Nanoencapsulation

The crop yield is tried to be increased by co-applying micronutrients and N, P, and K (NPK) fertilizers to soils that are deficient in micronutrients in order to meet the nutritional needs of billions of people in the world. The common point with micronutrients in diverse global agricultural ecosystems is that crop deficiencies increase with the low efficiency of crop use. Micronutrient use efficiency (MUE) is defined as the biomass yield per unit input of fertilizer and nutrient content (**Meena *et al.* 2014**). It was also reported that the interactions between micronutrients and macronutrients can affect crop yield positively or negatively. In other words, the interaction of fertilizer-micronutrients with macronutrients can occur as a synergistic, antagonistic, or neutral reaction that may affect the yield and quality of the product. It was determined that high amounts of P applied to the soil cause Cu deficiency in plants such as corn, beans, citrus, and tomato. It was reported that NPK fertilization for rice and wheat cultivation in India increases the crop yield whereas the bioavailability of micronutrients such as Zn becomes so limited, and as a result, it poses a big problem in Zn nutrition for humans (**Cakmak**

2009; Monreal et al. 2015). Despite the increase in crop yield with NPK fertilization, reasons such as the lack of increase in crop yield in regions with less favorable biophysical conditions and hidden hunger in people consuming products with low micronutrient values necessitate sustainable new solutions to produce crops with high crop yield

3. Success Stories

Biofortification, the process of enhancing the nutritional value of crops through conventional breeding, agronomy, or biotechnology, has shown promising successes in combating malnutrition and improving public health, particularly in regions where nutrient deficiencies are prevalent. Here are some notable success stories of biofortification:

- a) Golden Rice: Perhaps the most famous example, Golden Rice is a genetically modified rice variety developed to produce beta-carotene, a precursor of vitamin A. Vitamin A deficiency is a significant public health issue in many developing countries, leading to blindness and increased susceptibility to infections. Golden Rice aims to address this deficiency by providing a sustainable source of vitamin A in rice-based diets. Paine et al., 2005

Impact - The introduction of Golden Rice has shown positive results in addressing vitamin A deficiency. It has the potential to improve the health of millions of people who rely heavily on rice as a staple food.

- b) Orange Sweet Potato: Orange-fleshed sweet potato (OFSP) is a naturally biofortified variety rich in beta-carotene. Through efforts by organizations like the International Potato Center (CIP), OFSP has been introduced in several countries in sub-Saharan Africa, where vitamin A deficiency is prevalent. Promotion of OFSP consumption has led to improved vitamin A status among vulnerable populations, particularly women and children.

Impact - The consumption of these orange-fleshed sweet potatoes has led to increased vitamin A intake, positively impacting the health of communities and reducing the incidence of vitamin A deficiency-related health issues.

- c) Biofortified Maize: Biofortified maize varieties have been developed to enhance the levels of essential nutrients such as vitamin A, iron, and zinc. In regions where maize is a staple food, such as parts of Africa and Latin America, these varieties have the potential to address widespread nutrient deficiencies. For example, provitamin A maize varieties have been introduced in Zambia and other countries to improve vitamin A intake.

Impact - The adoption of biofortified maize has contributed to improved nutritional outcomes, addressing specific nutrient deficiencies in these regions and promoting better overall health.

- d) Iron-Biofortified Beans: Iron deficiency is a common micronutrient deficiency globally, particularly affecting women and children. Iron-biofortified bean varieties, developed through conventional breeding, have higher iron content compared to traditional varieties. These beans have been introduced in countries like Rwanda and the Democratic Republic of Congo, contributing to improved iron intake and reduced anemia prevalence **Tako et al., 2013.**

Impact - The consumption of these iron-biofortified beans has led to an increase in iron levels among populations, reducing the prevalence of iron-deficiency anemia, particularly in women and children.

- e) Zinc-Biofortified Wheat: Zinc deficiency is a significant public health concern, particularly in South Asia where wheat is a staple food. Zinc-biofortified wheat varieties have been developed to increase the zinc content of grains. Studies have shown that consumption of these varieties improves zinc status among consumers, potentially reducing the burden of zinc deficiency-related diseases.

Impact - The adoption of zinc-biofortified wheat has shown positive outcomes in improving zinc levels in the diet. This has implications for better overall health, particularly in preventing stunted growth in children.

These success stories demonstrate the potential of biofortification as a sustainable and cost-effective approach to improving

micronutrient intake and addressing malnutrition on a global scale. However, challenges such as regulatory hurdles, public acceptance, and ensuring equitable access to biofortified crops remain important considerations in further scaling up these efforts.

4. Future Aspects

The future of biofortification holds several promising aspects as researchers and agriculturalists continue to innovate and address challenges. Here are some future directions and potential developments in biofortification:

1. **Expanding Crop Varieties:** While biofortification efforts have primarily focused on staple crops like rice, wheat, maize, and sweet potato, there is potential to expand the range of biofortified crops. This could include legumes, vegetables, fruits, and other locally important crops, thereby addressing a broader spectrum of nutrient deficiencies.
2. **Enhancing Multiple Nutrients:** Current biofortification efforts often target individual nutrients such as vitamin A, iron, or zinc. Future research may focus on developing crops with enhanced levels of multiple nutrients, addressing multiple deficiencies simultaneously. This approach, known as “targeted multiple-nutrient biofortification,” could offer synergistic health benefits and more comprehensive nutritional improvements.
3. **Improving Nutrient Bioavailability:** In addition to increasing nutrient content, researchers are exploring ways to enhance the bioavailability of nutrients in biofortified crops. Strategies such as breeding for improved nutrient absorption, reducing antinutritional factors, and enhancing nutrient stability during storage and cooking could maximize the nutritional impact of biofortified crops.
4. **Utilizing Biotechnology:** Advances in biotechnology, including gene editing techniques like CRISPR-Cas9, offer new opportunities for accelerating the development of biofortified crops. These technologies enable precise modification of crop genomes to enhance nutritional traits while maintaining other desirable agronomic

characteristics. Biotechnology can also facilitate the development of biofortified crops with improved resilience to environmental stresses, contributing to sustainable agriculture.

5. **Addressing Climate Change Challenges:** Climate change poses significant challenges to global food security and nutrition. Future biofortification efforts may focus on developing climate-resilient crop varieties that can thrive under changing environmental conditions. This could involve selecting traits that confer tolerance to drought, heat, salinity, and other climate-related stresses while maintaining nutritional quality.
6. **Promoting Adoption and Access:** Ensuring widespread adoption and equitable access to biofortified crops remains crucial for maximizing their impact on public health. Future initiatives may involve community engagement, education campaigns, and partnerships with governments, NGOs, and private sectors to promote awareness, acceptance, and affordability of biofortified foods, particularly among vulnerable populations.
7. **Integration with Food Systems:** Biofortification efforts can be integrated into broader food system approaches to address malnutrition comprehensively. This includes promoting diversified diets, improving food processing and preservation techniques, strengthening food distribution networks, and supporting local agricultural systems to enhance access to nutrient-rich foods.

Overall, the future of biofortification holds immense potential to contribute to global efforts to combat malnutrition, improve public health, and achieve sustainable development goals. Continued investment in research, innovation and partnerships will be essential to realizing this potential and ensuring that biofortified crops reach those who need them most.

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HUMAN HEALTH TOOLS: BIO-FORTIFIED CROPS

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Abstract

Present scenario malnutrition is the major issues in human society. It is affected the human health with simultaneous working efficiency. It occurs unavailability of balance diet. Vegetables Play the Significance role due to rich sources of nutritive food. Vegetables provides carbohydrate, Protein, Minerals, Fiber & Vitamins. But due to intensive cultivation of several crops continuously from eight decades of Nineteen Century has steadily eroded the capacity of plant nutrients and affected the systems of macro and micro-nutrients synthesis. The quality and quantity of the vegetable, cereal, and fruit crops are not only influenced by the agrochemical applications but also by the stage and type of crops involved in the recycling of organic matter. Deficiency of micro-nutrients in soil also affected the produce quality such produce used as food also affect the human health. Several studies also observed that macro and micro nutrient deficiencies are widely observed in different crops. These deficiencies may affect human health and are associated with diseases and malnutrition. Bio fortified horticultural crops play a crucial role in addressing global malnutrition and improving public health. By enhancing the nutrient content of commonly consumed crops, bio fortification provides a sustainable and cost-effective strategy to deliver essential nutrients to vulnerable populations, thereby contributing to global health and development goals. Bio-fortified crops are plants that have been bred to increase their nutritional value, particularly in terms of vitamins and minerals. This enhancement can be achieved through traditional breeding techniques or modern biotechnological methods. The primary goal of bio-fortification is to address micro-nutrient deficiencies in populations that rely heavily on staple crops for their diet.

Introduction to Bio-fortification:

Bio-fortification is defined as the process of enhancing the nutritional quality of food crops by increasing their concentrations of essential vitamins and minerals. This enhancement is achieved through various methods, including conventional breeding, genetic engineering, and agronomic practices. The primary objective of bio-fortification is to address micronutrient deficiencies, often referred to as “hidden hunger,” which affects billions of people worldwide. By developing crops that are naturally richer in nutrients, bio-fortification aims to improve the nutritional status of populations, particularly in low- and middle-income countries where access to

diverse and nutrient-rich foods is limited.

The purpose of bio-fortified crops is multifaceted. Firstly, they serve as a sustainable and cost-effective solution to combat malnutrition, particularly among vulnerable groups such as women and children. Bio-fortification not only increases the availability of essential micronutrients in staple foods but also aims to improve overall health outcomes by reducing the prevalence of diet-related diseases. Additionally, bio-fortified crops can enhance food security by providing higher yields and better nutritional quality, which can lead to improved economic stability for farmers and communities. Ultimately, bio-fortification seeks to integrate nutritional

improvement into existing agricultural systems, ensuring that populations receive the necessary nutrients for optimal health and development without requiring significant changes to their dietary habits or agricultural practices.

Bio-fortification has a rich historical context that traces back to the early 20th century when food fortification began to gain traction as a public health intervention. The concept of enhancing food with essential nutrients to prevent deficiencies was first implemented in the 1920s with the introduction of iodine in salt to combat goiter. This early form of fortification laid the groundwork for subsequent nutritional interventions, but it primarily focused on processed foods rather than staple crops.

The modern concept of bio-fortification emerged in the late 1990s, spearheaded by researchers like Howarth Bouis, who recognized the need for a sustainable solution to address micronutrient deficiencies in populations reliant on staple crops. Bouis and his colleagues at the International Food Policy Research Institute (IFPRI) proposed the idea of increasing the nutrient density of crops through traditional breeding methods, which would allow for the direct consumption of nutrient-rich foods without the need for additional processing or supplementation. This innovative approach aimed to tackle “hidden hunger,” a form of malnutrition characterized by inadequate intake of essential vitamins and minerals.

The first significant bio-fortified crop, iron-rich beans, was developed and released in the early 2000s, followed by other crops such as provitamin A-enriched sweet potatoes and zinc-enriched wheat. These crops were designed to be culturally acceptable and agronomically viable, ensuring that they could be integrated into local farming systems and diets. The success of these initial efforts led to the establishment of programs like HarvestPlus, which focuses on promoting the development and dissemination of bio-fortified crops globally.

In recent years, advancements in biotechnology have further expanded the scope of bio-fortification. Genetic engineering techniques have been employed to create transgenic crops with enhanced nutrient profiles, such as Golden

Rice, which is fortified with vitamin A. These developments have sparked discussions about the role of biotechnology in addressing global malnutrition and have prompted regulatory considerations regarding the acceptance and safety of genetically modified organisms (GMOs).

Today, bio-fortification is recognized as a vital strategy in the fight against malnutrition, supported by international organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). It represents a sustainable and cost-effective approach to improving public health and nutrition, particularly in low- and middle-income countries where access to diverse and nutrient-rich foods is limited.

Importance of Bio-fortified Crops:

Micronutrient deficiencies are a significant global health issue, affecting over two billion people worldwide, particularly in low-income countries. These deficiencies are often referred to as “hidden hunger” because they can occur even when individuals consume sufficient calories but lack essential vitamins and minerals such as iron, zinc, and vitamin A. The consequences of micronutrient deficiencies are severe, leading to impaired physical and cognitive development, increased susceptibility to infections, and higher mortality rates, especially among vulnerable populations such as pregnant women, lactating mothers, and young children.

Addressing micronutrient deficiencies requires a multifaceted approach that includes dietary diversification, supplementation, and food fortification. Dietary diversification involves increasing the variety of foods consumed to ensure adequate intake of essential nutrients. However, in many regions, particularly in low-resource settings, access to a diverse range of foods is limited due to economic constraints or availability. Therefore, supplementation programs, which provide specific vitamins and minerals to at-risk populations, are critical. For instance, iron and folic acid supplements are commonly recommended for pregnant women to prevent anemia and support fetal development.

Food fortification is another effective strategy, where essential nutrients are added to commonly consumed foods to enhance their nutritional value.

This method has been successfully implemented in various countries, with examples including iodized salt, fortified flour, and vitamin A-enriched oils. Such interventions not only help prevent deficiencies but can also improve overall public health outcomes by reducing the incidence of nutrition-related diseases.

In emergencies, the risk of micronutrient deficiencies can increase due to disrupted food supplies and loss of livelihoods. In such situations, it is essential to ensure that food aid includes fortified products to meet the nutritional needs of affected populations. For example, organizations like UNICEF and the World Health Organization (WHO) have developed multiple micronutrient supplements tailored for vulnerable groups to help mitigate the impact of emergencies on nutritional status.

Overall, addressing micronutrient deficiencies is crucial for improving health outcomes, enhancing productivity, and fostering economic development. Continued efforts are needed to implement effective intervention strategies, raise awareness about the importance of micronutrients, and ensure that vulnerable populations have access to nutrient-rich foods.

Bio-fortification has a significant impact on public health and nutrition by addressing micronutrient deficiencies that affect billions of people worldwide. These deficiencies, often termed “hidden hunger,” can lead to severe health consequences, including impaired cognitive development, weakened immune systems, and increased mortality rates, particularly among vulnerable populations such as women and children. By enhancing the nutrient content of staple crops, bio-fortification provides a sustainable and cost-effective solution to improve dietary quality and overall health outcomes.

Bio-Fortified Crops in the Indian Context

Addressing Malnutrition

Bio-fortified crops play a crucial role in combating malnutrition in India, particularly among children and women. Micro nutrient deficiencies, such as those of iron, zinc, and vitamin A, are prevalent in India, leading to conditions like anemia, stunted growth, and compromised immune function. Bio-fortified crops

provide a sustainable solution to these deficiencies by enhancing the nutritional content of staple foods.

Enhancing Food Security

With a significant portion of the Indian population relying on staple crops like rice, wheat, and maize, bio-fortified varieties ensure that these staples are not just sources of calories but also rich in essential nutrients. This enhancement contributes to better overall health and productivity.

Economic Benefits

Bio-fortified crops can lead to economic benefits by reducing healthcare costs associated with treating micro nutrient deficiencies. Healthier populations are more productive, contributing positively to the economy.

Agricultural Sustainability

Bio-fortification efforts often include breeding for traits like pest resistance and climate resilience, which are crucial for sustainable agriculture in India. These traits help in maintaining crop yields and ensuring food availability despite environmental challenges.

Government Initiatives and Support

The Government of India, through various ministries and programs, supports the development and distribution of bio-fortified crops. Initiatives like the National Food Security Mission (NFSM) and collaborations with international organizations such as Harvest Plus are instrumental in promoting these nutrient-rich crops.

Improved Nutritional Status

Bio-fortified crops, such as iron-rich beans, vitamin A-enriched sweet potatoes, and zinc-enriched wheat, have been shown to significantly improve the nutritional status of consumers. For instance, studies conducted in Nigeria demonstrated that children consuming bio-fortified cassava exhibited improved vitamin A levels compared to those consuming non-bio-fortified varieties. Similarly, in Rwanda, women consuming iron-bio-fortified beans experienced increased hemoglobin and serum ferritin levels, indicating better iron status. These

findings highlight the potential of bio-fortification to directly enhance micronutrient intake and reduce the prevalence of deficiencies in target populations.

Economic Benefits

The economic impact of bio-fortified crops extends beyond individual health improvements. By increasing the nutritional quality of staple foods, bio-fortification can enhance productivity and reduce healthcare costs associated with malnutrition-related diseases. Additionally, bio-fortified crops can provide new livelihood opportunities for farming families, as they can sell their harvests at higher prices due to the added nutritional value. This creates a self-sustaining cycle where improved health leads to increased economic stability, further supporting community development.

Sustainability and Accessibility

Bio-fortification is recognized as one of the most sustainable methods for combating malnutrition. Unlike traditional fortification, which relies on processing and external nutrient additions, bio-fortified crops naturally contain higher levels of essential nutrients, thereby integrating nutrition into the food supply chain. This approach is particularly advantageous in rural areas where access to diverse foods and supplements may be limited. By focusing on staple crops, bio-fortification ensures that nutrient-rich foods are accessible to both urban and rural populations, addressing the nutritional needs of various demographic groups.

Challenges and Future Directions

Despite its benefits, the widespread adoption of bio-fortified crops faces challenges, including public acceptance, regulatory hurdles, and the need for education about their benefits. To maximize the impact of bio-fortification, it is essential to engage stakeholders across the agricultural value chain, from farmers to consumers, and to promote policies that support the integration of bio-fortified crops into national food systems. Continued research and development are necessary to enhance the nutrient profiles of crops and ensure their acceptance in diverse cultural contexts.

In conclusion, bio-fortification represents a

promising strategy for improving public health and nutrition by addressing micronutrient deficiencies through the development of nutrient-rich staple crops. By enhancing dietary quality and promoting economic stability, bio-fortification can contribute significantly to global efforts to combat malnutrition and improve health outcomes for vulnerable populations.

Methods of Bio-fortification:

Bio-fortification employs several methods to enhance the nutritional quality of food crops, focusing on increasing the density of essential vitamins and minerals. The primary methods of bio-fortification include:

1. **Conventional Breeding** Conventional breeding involves traditional agricultural practices where crops are selectively bred to enhance their nutrient content. This method relies on crossbreeding different varieties of a crop to produce offspring with desirable traits, such as higher levels of specific micronutrients. For instance, iron-rich beans and zinc-enriched wheat have been developed through this approach. This method is widely used in countries like India, where bio-fortified varieties of crops have been released to improve the nutritional status of the population.
2. **Genetic Engineering** Genetic engineering, or transgenic techniques, involves the direct manipulation of an organism's DNA to introduce new traits. This method allows for the precise enhancement of nutrient content by inserting specific genes associated with nutrient biosynthesis into the crop's genome. An example of this is Golden Rice, which has been genetically modified to produce beta-carotene, a precursor of vitamin A. Genetic engineering can provide a more rapid and targeted approach to bio-fortification compared to conventional breeding.
3. **Agronomic Practices** Agronomic practices refer to the application of specific agricultural techniques to increase the nutrient content of crops during their growth. This can include the use of micronutrient fertilizers, soil amendments, and foliar sprays to enhance the availability of essential nutrients in the soil. For example, applying zinc-enriched

fertilizers can significantly boost the zinc levels in crops like rice and wheat. This method is particularly useful in regions where soil deficiencies limit the natural nutrient content of crops.

These methods of bio-fortification—conventional breeding, genetic engineering, and agronomic practices—offer diverse strategies to combat micronutrient deficiencies globally. By integrating these approaches, bio-fortification aims to create nutrient-rich crops that can effectively improve the dietary quality of populations, particularly in areas where access to diverse and fortified foods is limited.

Key Bio-Fortified Crops in India:

India has been actively involved in the production and promotion of bio-fortified crops. The Indian Council of Agricultural Research (ICAR) and various state agricultural universities have been at the forefront of developing and distributing these nutrient-rich crops. Key institutions and states involved include:

Indian Council of Agricultural Research (ICAR)

- Spearheads research and development in bio-fortified crops.
- Collaborates with international organizations like Harvest Plus.

Punjab Agricultural University (PAU)

- Notable for its work on zinc-bio fortified wheat.

Indian Institute of Maize Research (IIMR)

- Develops pro-vitamin A-rich maize varieties.

State Agricultural Universities (SAUs)

- Various SAUs across states like Karnataka, Tamil Nadu, and Maharashtra are engaged in bio-fortification projects.

Description of Some Bio fortified Varieties

Bio-fortified Crop	Nutrient Enhanced	Health Benefits	Examples
Sweet Potato	Vitamin A	Improves vision, immune function, and reduces the risk of night blindness and other eye diseases	Orange-fleshed sweet potato
Cassava	Vitamin A	Enhances immune function, supports growth and development in children, and reduces morbidity and mortality from infectious diseases	Yellow cassava
Maize (Corn)	Provitamin A	Supports vision, immune system, and reproductive health	Orange maize
Rice	Iron	Prevents anemia, enhances cognitive function, and improves overall energy levels	Iron-bio-fortified rice
Beans	Iron, Zinc	Iron: Prevents anemia, Zinc: Supports immune function, wound healing, and DNA synthesis	Iron and zinc-rich beans
Banana	Provitamin A, Iron	Vitamin A: Enhances vision and immune function, Iron: Prevents anemia	Provitamin A and iron-rich bananas
Pearl Millet	Iron, Zinc	Iron: Prevents anemia, Zinc: Supports immune function, improves growth and development in children	Iron and zinc-rich pearl millet
Tomato	Lycopene, Beta-carotene	Lycopene: Reduces risk of chronic diseases, Beta-carotene: Precursor to vitamin A, supports vision and immune function	High-lycopene and beta-carotene tomatoes
Carrot	Beta-carotene	Precursor to vitamin A, supports vision, immune function, and skin health	High-beta-carotene carrots
Pumpkin	Provitamin A, Iron	Vitamin A: Enhances vision and immune function, Iron: Prevents anemia	High-provitamin A and iron-rich pumpkin
Cauliflower	Beta-carotene	Pusa Beete Kesari-1 rich in beete caroten	Psu Beta Kesary -1 is rich in Beeta Caroten

Nutritional Based Bio-Fortified Crops in India

1. Iron-Bio fortified Pearl Millet (Bajra)

- **Nutrient Enhanced:** Iron
- **Health Benefits:** Prevents anemia, supports cognitive function.
- **Varieties:** Dhanshakti

2. Zinc-Bio fortified Wheat

- **Nutrient Enhanced:** Zinc
- **Health Benefits:** Supports immune function, DNA synthesis, and wound healing.
- **Varieties:** WB02, WB03

3. Pro vitamin A-Bio fortified Maize

- **Nutrient Enhanced:** Provitamin A (Beta-carotene)
- **Health Benefits:** Supports vision, immune function, and skin health.
- **Varieties:** Pusa Vivek QPM 9 Improved

4. Iron and Zinc-Bio fortified Rice

- **Nutrient Enhanced:** Iron and Zinc
- **Health Benefits:** Prevents anemia, supports immune function, improves cognitive function.
- **Varieties:** DRR Dhan 45

5. Provitamin A-Bio fortified Sweet Potato

- **Nutrient Enhanced:** Provitamin A
- **Health Benefits:** Enhances vision, immune function, and reduces the risk of night blindness.
- **Varieties:** Bhu Sona, Bhu Krishna

Advantages of Bio-fortified Horticultural Crops:

- 1. Improved Nutrition:** Enhances the intake of essential vitamins and minerals, particularly in populations with limited access to diverse diets.
- 2. Disease Prevention:** Reduces the prevalence of nutrient deficiency-related diseases such as anemia, night blindness, and other health issues.
- 3. Child Development:** Supports the growth and cognitive development of children, leading to better educational and developmental outcomes.

4. Economic Impact: Reduces healthcare costs related to nutrient deficiencies and enhances productivity by improving the overall health of the population.

5. Sustainable Agriculture: Promotes agricultural diversity and resilience, as bio-fortified crops often have improved resistance to pests and environmental stressors.

Acceptance and Adoption of Bio-fortified Crops:

The acceptance and adoption of bio-fortified crops among farmers are critical for the success of bio-fortification initiatives aimed at combating micronutrient deficiencies. Understanding the factors influencing farmer acceptance and the agricultural practices associated with bio-fortified crops can help design effective strategies for implementation.

Key Determinants of Farmer Acceptance:

- 1. Socioeconomic Factors:** Farmers' socioeconomic status, including income level, education, and access to resources, significantly influences their willingness to adopt bio-fortified crops. Higher income and education levels often correlate with greater acceptance, as these farmers may have more access to information and resources to experiment with new crop varieties.
- 2. Institutional Support:** The role of government policies, agricultural extension services, and support from NGOs is crucial in promoting bio-fortified crops. Access to training, information, and financial support can enhance farmers' confidence in adopting these new varieties. For example, programs that provide education about the benefits of bio-fortified crops can lead to increased acceptance and willingness to plant these varieties in upcoming growing seasons.
- 3. Agronomic Factors:** The perceived agronomic performance of bio-fortified crops, such as yield potential, disease resistance, and adaptability to local growing conditions, plays a significant role in farmers' decisions. If farmers believe that bio-fortified varieties will perform well and provide economic benefits, they are more likely to adopt them.

4. **Psychological and Cognitive Factors:** Farmers' beliefs and perceptions about bio-fortified crops, including their nutritional benefits and marketability, can influence their adoption. Awareness of the health benefits associated with bio-fortified crops can motivate farmers to grow these varieties, especially if they see a demand for them in local markets.

Agricultural Practices

Farmers' agricultural practices are also influenced by their acceptance of bio-fortified crops. Key practices include:

- **Crop Rotation and Diversity:** Farmers may integrate bio-fortified crops into their existing crop rotation systems, promoting biodiversity and improving soil health. This practice can enhance the overall resilience of farming systems.
- **Seed Selection and Management:** Farmers who accept bio-fortified crops will likely prioritize the selection of high-quality seeds and adopt best management practices to maximize yields and nutrient content.
- **Market Engagement:** Successful adoption often involves engaging with local markets to ensure that bio-fortified crops are recognized and valued. Farmers may need training on marketing strategies to effectively promote their bio-fortified produce.

Challenges to Adoption

Despite the potential benefits, challenges remain in the acceptance and adoption of bio-fortified crops:

- **Limited Awareness:** Many farmers may not be aware of the nutritional advantages of bio-fortified crops or may have misconceptions about their performance compared to conventional varieties.
- **Access to Seeds:** Availability of high-quality seeds for bio-fortified crops can be a barrier, particularly in remote areas where supply chains are weak.
- **Cultural Preferences:** Cultural attitudes toward traditional crops can hinder the acceptance of new varieties, even if they offer nutritional benefits.

- **Case Studies of Successful Adoption:**
- Based on the search results, here are some key case studies highlighting successful adoption of bio-fortified crops:

Bio-fortified Mustard in India

A case study from Grameen Foundation India showcases their intervention to promote the adoption of bio-fortified mustard (BFM) among women farmers in Jharkhand, India. The intervention bundled social innovations like self-help group (SHG) and farmer producer organization (FPO) membership with technical innovations like training and knowledge dissemination. This multi-pronged approach resulted in successful adoption of BFM among the women farmers. Key factors enabling adoption included:

- Engaging multiple stakeholders like research institutions, farmer groups, and implementation organizations
- Demonstrating tangible benefits of BFM like higher oil content, improved nutrition, and reduced drudgery
- Providing technical guidance and knowledge support through ICAR-DRMR-FPO agreements

Bio-fortified Sweet Potato in Uganda

Harvest Plus has had success promoting orange-fleshed sweet potato (OFSP), a provitamin A-bio-fortified variety, in Uganda. OFSP was the most studied bio-fortified crop in the systematic review, demonstrating its potential for wide-scale adoption. Key factors that facilitated OFSP adoption included:

- Availability and accessibility of OFSP vines for planting
- Provision of information on nutritional benefits to consumers
- Marketability and premium pricing opportunities for farmers

Bio-fortified Maize in Nigeria

Pro-vitamin A-bio-fortified maize has also seen promising adoption in Nigeria. Maize was the second most studied bio-fortified crop in the review. Factors that enabled maize adoption included:

- Yield and agronomic performance comparable to traditional varieties
- Availability of seeds and information on nutritional benefits
- Potential for increased income from selling bio-fortified maize.

These case studies demonstrate that successful adoption of bio-fortified crops is possible when a combination of factors are addressed - from availability and accessibility, to agronomic performance, to consumer awareness and willingness to pay. Targeted interventions that engage multiple stakeholders and address context-specific barriers can facilitate the uptake of these nutritionally-enhanced crops.

Challenges in Bio-fortification:

Bio-fortification, while a promising strategy to combat micronutrient deficiencies, faces several challenges that can hinder its effectiveness and widespread adoption. These challenges can be categorized into several key areas:

1. **Public Acceptance** One of the most significant challenges is gaining public acceptance of bio-fortified crops. Changes in sensory attributes, such as color and taste, can lead to consumer hesitation. For example, the introduction of Golden Rice, which has a yellow hue due to its beta-carotene content, faced skepticism from consumers who were accustomed to traditional rice varieties. Education and awareness campaigns are essential to inform consumers about the health benefits of bio-fortified crops and to alleviate concerns regarding their sensory qualities.
2. **Agronomic Performance** Farmers are more likely to adopt bio-fortified crops if they demonstrate competitive agronomic traits, such as high yield, disease resistance, and drought tolerance. If bio-fortified varieties do not perform well compared to traditional crops, farmers may be reluctant to switch. Therefore, ensuring that bio-fortified crops meet or exceed the agronomic performance of conventional varieties is crucial for their acceptance among farmers.
3. **Availability and Accessibility** The availability of bio-fortified seeds and crops in local markets is essential for consumer adoption. In many regions, access to bio-fortified varieties may be limited due to inadequate distribution networks or lack of investment in seed production. Ensuring that bio-fortified crops are accessible to both farmers and consumers is vital for the success of bio-fortification initiatives.
4. **Economic Barriers** The initial costs associated with adopting bio-fortified crops can be a barrier for farmers, particularly in low-income settings. Investment in new seed varieties, training, and agronomic practices may require financial resources that are not readily available. Additionally, market dynamics, such as the pricing of bio-fortified crops compared to traditional varieties, can influence farmers' decisions to adopt these crops.
5. **Nutritional Bioavailability** Even if bio-fortified crops are consumed, the bioavailability of the nutrients they contain can vary based on several factors, including the presence of dietary inhibitors or enhancers. For instance, the absorption of iron can be affected by the presence of phytates in other foods. Addressing these nutritional challenges is essential to ensure that bio-fortified crops effectively improve micronutrient status in consumers.
6. **Cultural Acceptance** Cultural attitudes toward traditional crops can hinder the acceptance of bio-fortified varieties. In many regions, staple foods are deeply ingrained in cultural practices and preferences. Therefore, bio-fortification efforts must consider local dietary habits and cultural contexts to encourage acceptance and integration of bio-fortified crops into local diets.

Addressing these challenges requires a multifaceted approach that includes education and awareness campaigns, investment in agronomic research, improved distribution networks, and consideration of local cultural contexts. By overcoming these barriers, bio-fortification can play a significant role in improving global nutrition and combating micronutrient deficiencies effectively.

Monitoring and Evaluation of Bio-fortification Programs:

Monitoring and evaluating bio-fortification programs is crucial for assessing their effectiveness and ensuring they achieve intended health outcomes. Key aspects include:

Programme Impact Pathway (PIP)

- Provides a framework outlining expected outcomes and how activities lead to results
- Guides program design by establishing clear objectives
- Enables tracking of standardized indicators across regions and crops
- Facilitates continuous learning and adaptation of strategies.

High-Level Indicators (HLI)

- A set of 17 HLI recommended for a harmonized global M&E framework
- Tracks critical results along the bio-fortification implementation pathway
- Examples include production metrics, consumption rates, and nutritional impact

Data Collection and Analysis

- Routine monitoring of production, sales, and consumption data
- Surveys to evaluate consumer awareness, acceptance, and nutritional status
- Cross-country learning using standardized data collection methods.

Challenges

- Lack of harmonization in indicators and metrics across programs
- Resource constraints limiting comprehensive M&E implementation
- Cultural variability in dietary habits complicating impact evaluation.

Addressing these challenges and continuing research to test and revise the M&E framework will be critical for maximizing bio-fortification's potential to improve nutrition globally. Using standardized indicators and tools enables tracking progress, assessing impacts, and making necessary adjustments for effective program implementation.

Future Directions and Innovations:

Future directions and innovations in bio-fortification are essential for enhancing the nutritional quality of staple crops and addressing global micronutrient deficiencies.

1. **Integration of Multiple Strategies** Future research should emphasize the integration of various bio-fortification strategies, combining genetic, agronomic, and breeding approaches. This multi-faceted strategy can maximize nutrient enhancement and improve the overall resilience of crops. For instance, combining conventional breeding with modern biotechnological techniques can yield crops that not only have higher nutrient content but also possess traits such as disease resistance and drought tolerance, making them more suitable for diverse growing conditions.
2. **Genetic Engineering Advances** Advancements in genetic engineering hold significant promise for bio-fortification. Techniques such as CRISPR/Cas9 gene editing can be utilized to precisely enhance the nutrient profiles of crops. This technology allows for targeted modifications that can improve the bioavailability of essential micronutrients, making bio-fortified crops more effective in combating deficiencies. Continued research in this area can lead to the development of new varieties that are tailored to specific nutritional needs in different regions.
3. **Focus on Nutritional Bioavailability** Future innovations should also address the bioavailability of nutrients in bio-fortified crops. While increasing micronutrient content is essential, ensuring that these nutrients are easily absorbed by the human body is equally important. Research into the interactions between different nutrients and dietary components can help optimize the formulation of bio-fortified crops to enhance their health benefits.
4. **Consumer Engagement and Education** Increasing consumer awareness and acceptance of bio-fortified crops is crucial for their success. Future initiatives should focus on comprehensive education campaigns that

highlight the health benefits of bio-fortified foods. Engaging local communities and stakeholders in the development and promotion of bio-fortified crops can foster acceptance and encourage consumption. This can include demonstrations of cooking methods that maximize the nutritional benefits of bio-fortified foods.

5. **Policy Support and Investment** To facilitate the widespread adoption of bio-fortified crops, strong policy support and investment are needed. Governments and organizations should prioritize funding for bio-fortification research, development, and dissemination of bio-fortified varieties. Policies that incentivize farmers to grow bio-fortified crops and promote their use in food assistance programs can significantly enhance their impact on public health.
6. **Monitoring and Evaluation Frameworks** Developing robust monitoring and evaluation frameworks is essential for assessing the effectiveness of bio-fortification programs. Establishing standardized indicators and methodologies will allow stakeholders to track progress, evaluate impacts, and make data-driven decisions to improve program implementation. This will ensure that bio-fortification initiatives are responsive to the needs of target populations and can adapt to emerging challenges.

Conclusion

Bio fortified horticultural crops play a crucial role in addressing global malnutrition and improving public health. By enhancing the nutrient content of commonly consumed crops, bio fortification provides a sustainable and cost-effective strategy to deliver essential nutrients to vulnerable populations, thereby contributing to global health and development goals.

In conclusion, bio-fortification represents a promising and innovative approach to combat micronutrient deficiencies, which affect billions of people worldwide. By enhancing the nutritional quality of staple crops, bio-fortification aims to address “hidden hunger” effectively and

sustainably. The primary methods of bio-fortification include conventional breeding, genetic engineering, and agronomic practices. These methods focus on improving the nutrient content of crops while ensuring they remain agronomically viable. Key bio-fortified crops, such as maize, rice, beans, sweet potatoes, and cassava, have been developed to target specific micronutrient deficiencies prevalent in various regions. Acceptance and adoption of bio-fortified crops are influenced by several factors, including consumer awareness, education, availability, agronomic performance, and marketability. Providing clear information about the health benefits of bio-fortified crops and ensuring their accessibility are crucial for successful implementation. Despite its potential, bio-fortification faces challenges such as public acceptance, agronomic performance, availability of seeds, economic barriers, and cultural preferences. Addressing these challenges requires a multifaceted approach that includes education campaigns, investment in research, improved distribution networks, and consideration of local contexts. Monitoring and evaluating bio-fortification programs is essential for assessing their effectiveness and ensuring they achieve intended health outcomes. The Programme Impact Pathway (PIP) and standardized high-level indicators can help track progress and outcomes, enabling stakeholders to make data-driven decisions to improve program implementation. Future directions in bio-fortification should focus on innovations in genetic engineering, a focus on nutritional bioavailability, comprehensive consumer engagement, supportive policies, and integrated strategies. By leveraging these approaches, stakeholders can enhance the impact of bio-fortification initiatives and contribute to the fight against malnutrition. Bio-fortification holds significant potential to improve global nutrition and public health. By addressing the challenges and embracing innovative solutions, stakeholders can effectively implement bio-fortification programs that enhance food security and contribute to the well-being of vulnerable populations worldwide.

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EFFECT OF DIFFERENT NITROGEN LEVELS AND FYM ON GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.).

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Abstract

The experiment was carried to determine the Effect of different Nitrogen levels and FYM on Growth, and Yield of wheat (*Triticum aestivum* L.) during rabi (winter) season 2021-22 at the Agronomy Research Farm, Agriculture Department, Himgiri Zee University, Selaqui, Dehradun Uttarakhand. Experiment was conducted on wheat variety of W-75. The soil of experimental site was sandy loam in texture pH 7.27, Electrical conductivity (EC) 0.18 dSm⁻¹, Organic Carbon (4.9 g Kg⁻¹) low, alkaline KMnO₄ N 265.30 Kg ha⁻¹, Olson -P 24.88 Kg ha⁻¹ ammonium acetate extractable K 108.70 Kg ha⁻¹. The treatments comprised of 4 level of nitrogen N₁ (60 kg N/ha), N₂ (90 kg N/ha), N₃ (120 kg N/ha), N₄ (150 kg N/ha) and one level of farm yard manure at which FYM was applied @ 6 tonnes ha⁻¹ with the three levels of nitrogen (60, 90 and 120 kg ha⁻¹) in the mode of soil application. There were 8 treatments combinations T₁ Control (without fertilizer), T₂ (60 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹), T₃ (90 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹), T₄ (120 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹), T₅ (60 kg N + 60 kg P₂O₅ + 60 kg K₂O + FYM 6 tones ha⁻¹ a) T₆ (90 kg N + 60 kg P₂O₅ + 60 kg K₂O + FYM 6 tones ha⁻¹), T₇ (120 kg N + 60 kg P₂O₅ + 60 kg K₂O + FYM 6 tones ha⁻¹), and T₈ (150 Kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹) replicated thrice in a randomized block design with in 24 plots. The results revealed that the application of 120Kg Nitrogen with Farm yard manure @ 6tones ha⁻¹ gave the maximum plant height, number of tillers m⁻², dry matter accumulation, and yield attributing characters, grain yield, straw yield, and biological yield. The maximum plant height **86.75 cm**, number of tillers 93.68 m⁻¹ row length, and dry matter accumulation 751.75 g m⁻¹ row length respectively was recorded in T₇ where 6 t ha⁻¹ FYM was applied with 120 Kg nitrogen in the experimental year followed by T₈ where 150 kg nitrogen was applied with recommended P and K. The similar trends were also recorded in the grain, straw and biological yield. Maximum grain yield (37.63 q ha⁻¹), straw yield (50.36 q ha⁻¹) and biological yield (87.99 q ha⁻¹) in the treatment T₇ where 6 t ha⁻¹ FYM was applied with the combination of 120 Kg N ha⁻¹ which were statistically at par with the treatment T₈ (36.20, 48.66 q/ha and 85.19 q ha⁻¹ respectively) where 150 kg N ha⁻¹ was applied.

Introduction

Wheat (*Triticum aestivum* L.) is the world's most outstanding crop that excels all other cereals both in area and production, known as the king of cereals. It is the single most important cereal crop that has been considered an integral component of the food security system of the several nations of Europe, West Asia, and North Africa. It ranks first

in the world, among the cereals in respect of an area (219 m ha) and production (715.9 m tones) (**Anonymous 2016-17**). It is primarily grown in temperate regions and also at higher altitude under tropical climate areas in winter season. In India, it is grown an area of 30.79 million hectares with the production of 98.51 million tonnes and average productivity of 3.20 t ha⁻¹ (**Anonymous, 2017-18**). India is concerned, about 91% of the

total wheat production is contributed by northern states like Uttar Pradesh, Haryana, and Punjab, where Uttar Pradesh ranks first with respect to area (9.65 m ha) and production (26.87 m tones) but the productivity is much lower (2784 kg ha⁻¹) as compared to Punjab and Haryana (4511 kg ha⁻¹) (**Anonymous, 2016-17**). In Uttarakhand, agro-climate conditions vary from sub-tropical to temperate. During 2011-12, in hilly region, wheat yield from 1.96 lakh hectare was recorded to be 2.64 lakh tones showing average productivity of 13.4 q ha⁻¹. Whereas, in the plain areas, production was noted as 35.7 q ha⁻¹ followed by productivity of 23.8 q ha⁻¹. In Uttarakhand, wheat is grown on 0.3 m ha area with production and productivity of 0.84 mt and 2.33 t ha⁻¹ respectively (**Anonymous, 2014**). In an experiment conducted Rudraprayag district of Uttarakhand under the front line demonstration (FLD), wheat yield obtained was 2.15 t ha⁻¹ which is 28.83% more than the yield from field with only traditional practices used by farmer (1.67 t ha⁻¹) (**Singh 2017**). Among the major nutrients, nitrogen is most essential nutrient among essential plant nutrients, plays key role in plant growth, development and production. Nitrogen is one of the major factors that plays important role in plant metabolism and determines the crop vigor and yield (**Korres and Froud, 2000**). Nitrogen is essential for protein production in plants, which is the direct or indirect source of protein for animal and human nutrition (**Prasad, 2003**). Plant needs adequate dose of chemical fertilizer to meet its nitrogen requirements which increases the number of tillers, spikelets, grains, spike length and weight of the grain (**Ali et al, 2000**). Although increased levels of production can be achieved by increased use of fertilizers, but continuous use of chemical fertilizers alone may lead to decline in productivity, loss of secondary micronutrients and some detrimental effect on physico-chemical properties of soil (**Joy et al., 2018, Bhatt, 2017**). And may not be so remunerated unless the fertility of the soil is maintained at sustainable levels by application of organic manure. Therefore, to maintain soil fertility and productivity at a sustainable level for long duration, use of organic manure is quite essential. Use of organic and inorganic nutrient resources together not only maintain soil fertility and provide proper nutrition

to the crop, it is environment friendly and cost effective approach for cultivation. (**Hassan et al., 2018**). Integrating the organic and inorganic sources of Nitrogen is a beneficial practice which increases the efficiency of utilization of Nitrogen (**Zahoor et al. 2015**). Integrating use of inorganic fertilizers with FYM improves the yield in wheat crop more than inorganic fertilizers or FYM used separately. It shows impressive results and is thus recommended for optimum wheat production (**Rathi et al, 2019**).

Material and Methods

The experiment was performed at the Agronomy Research Farm, Agriculture Department, Himgiri Zee University, Selaqui, Chakrata Road, Dehradun, and Uttarakhand during Rabi season 2021-2022. The experimental site is located in Dehradun in the foothill of the lower Himalayas in the Shivalik range at 650 m MSL. The site is situated at 31° 21' 50" N latitude and 78° 18' 27" E longitude. The soil of experimental site was sandy loam in texture pH 7.27, Electrical conductivity (EC) 0.18 dSm⁻¹, Organic Carbon (4.9 g Kg⁻¹) low, alkaline KMnO₄ N 265.30 Kg ha⁻¹, Olson -P 24.88 Kg ha⁻¹ ammonium acetate extractable K 108.70 Kg ha⁻¹. The treatments comprised of 4 levels of nitrogen N₁ (60 kg N/ha), N₂ (90 kg N/ha), N₃ (120 kg N/ha), N₄ (150 kg N/ha) and one level of farm yard manure at which FYM was applied @ 6 tonnes ha⁻¹ with the three levels of nitrogen (60, 90 and 120 kg ha⁻¹) in the mode of soil application. There were 8 treatments combinations T₁ Control (without fertilizer), T₂ (60 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹), T₃ (90 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹), T₄ (120 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹), T₅ (60 kg N + 60 kg P₂O₅ + 60 kg K₂O + FYM 6 tonnes ha⁻¹) T₆ (90 kg N + 60 kg P₂O₅ + 60 kg K₂O + FYM 6 tonnes ha⁻¹), T₇ (120 kg N + 60 kg P₂O₅ + 60 kg K₂O + FYM 6 tonnes ha⁻¹), and T₈ (150 Kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹) replicated thrice in a randomized block design. The farm yard manure @ 6 t ha⁻¹ were applied at time of sowing with the combination of different nitrogen level. While the calculated dose of Urea, Di ammonium Phosphate (DAP), Muriate of Potash (MOP), were used to provide N, P, K, and micronutrients as per treatments in T₂-T₈. Whereas in T₁ control no fertilizers were used. A

half dose of N, full dose of P, K, and farm yard manure were applied at the time of sowing while remaining half dose of N were applied in three equal splits at the Crown root initiation, Tillering and Late jointing stages of wheat. Growth observations were recorded at 30 and 60 day after sowing (DAS) and at the harvesting of the wheat crop. Yield attributes were recorded at harvest and grain and straw yield was recorded plot wise after threshing of produce. After cleaning and drying the to 14 per cent moisture. The yield of net plot, thus converted to $q\ ha^{-1}$. Dry weight of straw collected from net plot was recorded after sun grains; the grain yield was recorded in kg per plot. The entire data was analyzed statistically by using ANOVA. Chemical analysis of soil sample was done by using standard methods in the Department of agriculture Himgiri Zee University, Selaqui, Chakrata Road Dehradun Uttarakhand.

Results and Discussion

Plant height

The data regarding the application effect of different Nitrogen levels and FYM (Farm Yard Manure) on plant height of wheat at 30, 60 DAS and harvesting during 2022 are shown in Table.1 It is clear from the table that measured plant height was affected significantly by different treatments at the entire observation interval during the experimental year. Plant height increased at faster rate till 60 DAS while after that the increment in plant height was slower. The plant height measured at 30 DAS ranged from 18.85 to 29.76 cm during the experimental year respectively under different treatments and affected significantly with the application of different treatments. Maximum plant height was recorded with T_7 where 120 kg was applied with the combination of FYM 10 toes ha^{-1} . Which was significantly at par with the treatments T_8 , T_6 , T_5 , T_4 and T_3 and significantly superior than the treatment T_1 control which was no fertilizer was used. Regarding nitrogen nutrition practices, plant height as increased significantly with increasing levels of nitrogen from 60, 90, 120 and 150 $kg\ ha^{-1}$ alone and combination with FYM (6 tones ha^{-1}). The combination of nitrogen 120 $kg\ ha^{-1}$ with FYM (6 tones ha^{-1}) was found significantly superior followed by treatment T_8

where 150 $kg\ N\ ha^{-1}$ was applied with recommended P and K with respect to the plant height over the rest of nitrogen applied treatments. The minimum plant height was observed in the treatment T_1 control (Without fertilizer). Plant height increases by 31.93 to 57.82 per cent with increase the levels of nitrogen alone and in combination with FYM than T_1 control.

At 60 DAS stage plant height ranged from **58.42** to **72.52** cm during the experimental year respectively under different treatments and varied significantly than the rest of treatments. Plant height increased by 8.57 to 24.14 per cent. At this stage the maximum plant height **72.52 cm** was recorded in T_7 where 6 t ha^{-1} FYM was applied with 120 Kg nitrogen in the experimental year followed by T_8 (**71.63 cm**) where 150 kg nitrogen was applied with recommended P and K. With exception of T_1 , T_2 , T_3 , and T_4 , rest of the treatments having nitrogen application alone and combination with FYM were found statistically at par in respect of plant height at 60 DAS during the experimental years. At this stage also comparatively lower plant height was recorded in the treatments where nitrogen was applied alone than the combination with FYM. At 90 DAS stage increment of 4.79 to 15.09 per cent in plant height was found during experimental year. At this stage maximum plant height (**88.00 cm**) was recorded in T_7 (6 t ha^{-1} FYM with 120 $kg\ N\ ha^{-1}$) followed by T_8 (**85.67 cm**) where 150 kg nitrogen with recommended P and K was applied. The highest plant height at 90 DAS was observed in the treatment T_7 which was significantly at par with the treatments T_8 , T_6 and significantly superior than the rest of the treatments during the experimental year. At harvest stage plant height ranged from **74.34** to **86.75** cm during the experimental year respectively under different treatments and varied significantly than the rest of treatments. Plant height increased by 5.25 to 16.69 per cent. At this stage the maximum plant height **86.75 cm** was recorded in T_7 where 6 t ha^{-1} FYM was applied with 120 Kg nitrogen in the experimental year followed by T_8 (**84.79 cm**) where 150 kg nitrogen was applied with recommended P and K. With exception of T_1 , T_2 , and T_3 rest of the treatments having nitrogen application with recommended P and K and the combination with FYM were found statistically at par in respect of

plant height at harvest during the experimental years. At this stage also comparatively lower plant height was recorded in the treatments where nitrogen was applied alone than the combination with FYM. At all growth stages highest plant height was recorded in T₇ where 6 t ha⁻¹ FYM with 120 kg nitrogen was applied and equally good with the treatment T₈ where 150 kg nitrogen was applied with recommended P and K. Plant height of wheat at different stage was affected significantly by different treatments. The plant height recorded in T₇ (120 kg N + 60 kg P₂O₅ + 60 kg K₂O + 6 t ha⁻¹ FYM) was significantly higher than the rest of the treatments during the experimental year. Plant height was slightly lower in the treatments receiving nitrogen nutrition with the combination of recommended P and K than the treatments receiving nitrogen with the combination of recommended P, K and FYM. This effect may be supposed due to adequate availability of NPK and micronutrients with the application of recommended NPK and FYM. On the decomposition of FYM many essential plant nutrient become available to plant and many chelating agents are produced which increased the availability of micronutrients and dissolution of minerals which naturally found in the soil. The balanced supply of nutrients plays an important role for rapid growth and development of a crop. Cells protein content increase as the application of nitrogen increase and size of plant cell increases, as a result of that leaf area and photosynthesis rate rises which ultimately make the plant taller (Wysocki et al., 2007). The increase in plant height was because nitrogen increases leaf area which results in high rate of photosynthesis, more production of assimilates and plant dry matter. These results are similar to Liaqat et al., (2003) who also reported that plant height was significantly increased by different doses of nitrogen. Application of nitrogen significantly increased the growth parameters. Application of 120 kg N/ha produced significantly taller plants, more number of tillers and dry matter than all other levels of nitrogen. Similar result also found by (Ullah et al., 2018).

Number of tillers (m⁻¹ row length)

The data regarding the application effect of different Nitrogen levels and FYM (Farm Yard

Manure) on number of tillers m⁻¹ row length of wheat at 60 DAS and at harvest during 2021 are shown in Table.2. It is clear from the table that measured number of tillers m⁻¹ row length was affected significantly by different treatments at the entire observation interval during the experimental year. Number of tillers increased at faster rate till 60 DAS while after this no further increment in number tillers. The number of tillers measured at 60 DAS ranged from 53.97 to 93.68 m⁻¹ row length during the experimental year respectively under different treatments. The highest number of tillers was observed in the treatment T₇ (93.68 m⁻¹) which was significantly higher than the rest of treatment and at par with the treatment T₈ (91.25 m⁻¹). The minimum number of tillers was observed in the treatment T₁ (53.97) control where no fertilizer was used. The number of tillers increases with increases the level of N alone and combination with FYM. The number of tillers m⁻¹ increases from 19.32 to 73.57 per cent in the different treatments than the control. The number of tillers measured at Harvest ranges from 47.76 to 90.78 per m⁻¹ row length during the experimental year under the different treatments. The higher number of tillers per m⁻¹ row length was observed in the treatment T₇ (90.78 m⁻¹) which was significantly higher than the rest of treatment and at par with the treatment T₈ (88.45 m⁻¹). The minimum number of tillers was observed in the treatment T₁ (47.76) control where no fertilizer was used. The number of tillers increases in the treatment where increases the level of N alone and combination with FYM. The number of tillers per m⁻¹ row length increases from 28.24 to 90.07 per cent in the different treatments than the control. This effect may be supposed due to nitrogen has a vital role in cell division and elongation. Thus nitrogen favored greater assimilation of protein and carbohydrates. These two compound present in meristematic region of the plant induce rapid cell elongation which ultimately result in better plant growth. Tillering ability is genetically controlled but it also much dependent on other organic input and increasing nitrogen supply further increasing the tiller number. The interaction effect of nitrogen and FYM treatments on number of tillers/m² was found to be significant. The balanced supply of nutrients plays an important role for rapid growth

and development of a crop. Organic manures supply both macro and micro-nutrients and also improve the availability of native nutrients. Application of 120 kg N/ha significantly increased growth parameters, yield and yield attributes as compared to control. Application of 15 t/ha FYM along with 120 kg N/ha significantly improved the growth and yield of wheat. Similar results were reported by **Kavinder (2019) and Kumar et al. (2001)** also reported that increasing dose of nitrogen significantly increased the number of spike bearing tiller. These results are confirmatory to those revealed by **Ullah et al. (2018)**,

Dry matter accumulation (g m⁻¹ row length)

The data regarding the application effect of different Nitrogen levels and FYM (Farm Yard Manure) on Dry matter accumulation (g m⁻¹ row length) of wheat at 30, 60 DAS and at harvest during 2021 are shown in Table.2. It is clear from the table that measured dry matter accumulation (g m⁻¹ row length) was affected significantly by different treatments at the entire observation interval during the experimental year. The number dry matter accumulation (g m⁻¹ row length) measured at 30 DAS ranged from 47.12 to 62.43 (g m⁻¹ row length) during the experimental year respectively under different treatments. The maximum dry matter accumulation (g m⁻¹ row length) was observed in the treatment T₇ (62.43 g m⁻¹ row length) which were significantly higher than the rest of treatments and at par with the treatment T₈ (57.35 g m⁻¹ row length) and T₆ (56.36 g m⁻¹ row length). The minimum dry matter accumulation (g m⁻¹ row length) was observed in the treatment T₁ (47.12 g m⁻¹ row length) Control where no fertilizer was applied. The dry matter accumulation (g m⁻¹ row length) increases with increases the level of N alone and combination with FYM. The dry matter accumulation (g m⁻¹ row length) increases from 4.39 to 32.49 per cent in the different treatments than the control. The number dry matter accumulation (g m⁻¹ row length) measured at 60 DAS ranged from 283.96 to 373.99 (g m⁻¹ row length) during the experimental year respectively under different treatments. The maximum dry matter accumulation (g m⁻¹ row length) was observed in the treatment T₇ (373.99 g m⁻¹ row length) which were significantly higher

than the rest of treatments. The minimum dry matter accumulation (g m⁻¹ row length) was observed in the treatment T₁ (283.96 g m⁻¹ row length) Control where no fertilizer was applied. The dry matter accumulation (g m⁻¹ row length) increases with increases the level of N alone and combination with FYM. The dry matter accumulation (g m⁻¹ row length) increases from 3.91 to 31.70 per cent in the different treatments than the control. The number dry matter accumulation (g m⁻¹ row length) measured at harvest ranged from 589.92 to 751.75 (g m⁻¹ row length) during the experimental year respectively under different treatments. The maximum dry matter accumulation (g m⁻¹ row length) was observed in the treatment T₇ (751.75 g m⁻¹ row length) which were significantly higher than the rest of treatments. The minimum dry matter accumulation (g m⁻¹ row length) was observed in the treatment T₁ (589.92 g m⁻¹ row length) Control where no fertilizer was applied. The dry matter accumulation (g m⁻¹ row length) increases with increases the level of N alone and combination with FYM. The dry matter accumulation (g m⁻¹ row length) increases from 3.14 to 27.43 per cent in the different treatments than the control. This result might be recorded due to increasing the N level increased plant height, tillers m⁻¹ row length, no. of leaves leaf area index indicating higher chlorophilic area improving photosynthetic efficiency of plant under 150 Kg N ha⁻¹ and 120 kg N ha⁻¹ with FYM @6t ha⁻¹. Application of nitrogen significantly increased the growth parameters. Application of 120 kg N ha⁻¹ produced significantly taller plants, more number of tillers and dry matter accumulation than all other levels of nitrogen. Similar results were reported by **Singh and Agrawal (2005)**. Such improvement in dry matter accumulation due to N application has also been reported by **Ali et al. (2011) and Shirazi et al. (2014)**. The higher dose of N led to higher accumulation of dry matter, thus the effect is reflected in the form of crop growth rate between different sub stages **Satyanarayana et al. (2017)** also reported similar results.

Grain yield (q ha⁻¹)

It is clear from the table.3 that grain yield of wheat ranged from 17.800 to 37.633 qha⁻¹ during the experimental year respectively under different

treatments. The maximum grain yield was observed in the treatment T₇ (37.633) which were significantly higher than the rest of treatment and at par with the treatment T₈ (36.200). The minimum grain yield was recorded in the treatment T₁ (17.80) control where nitrogen was not applied and which was significantly differ then the other treatments. The grain yield increases with increases the level of N alone and combination with FYM. The grain yield increases from 18.53 to 111.42 per cent in the different treatments than the control. Similar result also recorded by **Ullah et. Al.,(2018)** Wheat grain yield was also significantly increased by different levels of nitrogen. Maximum grain yield (5576 kg ha⁻¹) was obtained from T₆ while minimum grain yield (1881.3 kg ha⁻¹) was recorded from the treatment where no application of nitrogen was done. Among all the essential nutrients applied to the plants nitrogen is the major one which has a key role in the process of photosynthesis. Increased rate of photosynthesis by the high dose of nitrogen gave more yield because large amount of dry matter, more assimilates were produced and transported to fill the seeds as a result of more applied nitrogen.

Straw yield (q ha⁻¹) The data are shown in Table.3 the straw yield ranged from 27.36 to 50.36 qha⁻¹ during the experimental year respectively under different treatments. The maximum straw yield was observed in the treatment T₇ (50.36) which were significantly higher than the rest of treatments and at par with the treatment T₈ (48.66) and T₆ (46.16). The minimum straw yield was observed in the treatment T₁ (27.36) control where no fertilizer was applied. The straw yield increases with increases the level of N alone and combination with FYM. The straw yield increases from 17.90 to 84.06 per cent in the different treatments than the control. **Singh and Singh. (2017)** also recorded the similar result the wheat yield was significantly affected by nitrogen fertilizer, FYM and their interaction. Stover yield increased under different N levels was significantly higher over control. Straw production showed trend similar to grain yield with higher values recorded with 12.0 kg N ha⁻¹. Grain and straw yield of wheat increased significantly with the application of FYM. The increase in wheat grain yield was 24.2% with application of 7.5 t

FYM ha⁻¹ over the control. It is might be due to steady decomposition of FYM and release of nutrients throughout the crop growth period coupled with better assimilation of nutrients (**Kumar et al. 2015, Singh et al. 2016**).

Biological yield (q ha⁻¹)

The data are shown in Table.3 the biological yield ranged from 45.16 to 87.993 during the experimental year respectively under different treatments. The highest biological yield was found in the treatment T₇ (87.993) which were significantly higher than the rest of treatments and statistically at par with the treatment T₈ (84.86). The minimum biological yield was observed in the treatment T₁ (45.16) control where no fertilizer was applied. The biological yield significantly increases with increases the level of N alone and combination with FYM. The biological yield increases from 18.15 to 94.84 per cent in the different treatments than the control. Maximum grain yield (37.63 q ha⁻¹), straw yield (50.36 q ha⁻¹) and biological yield (87.99 q ha⁻¹) were recorded under application of FYM 6 t ha⁻¹ with the combination of 120 Kg N ha⁻¹ in rabi season which were statistically at par with the treatment T₈ (36.20, 48.66 q/ha and 85.19 q/ha respectively) where 150 kg N ha⁻¹ was applied in rabi season while significantly higher among the treatments receiving FYM and N application. The beneficial effect of organic manures on grain, straw and biological yields might be assigned to the fact that after proper decomposition and mineralization, these manures supplied available plant nutrients directly to the plants and also had solubilizing effect on fixed forms of nutrients in soil. **Singh and Agarwal (2004)** also reported higher yield of wheat with increasing dose of FYM. Grain, straw and biological yield was increased due to with nitrogen's effect may be linked mostly to its role in the stimulation of numerous physiological processes such as cell division and cell elongation, which resulted in more photosynthetic area, which boosted photosynthetic production and, as a result, spike and grain numbers. The promoting effects of nitrogen on spikes number m⁻² and grains number spike⁻¹. Similar result was reported by **El.Sayed and Hammad (2007)**, and **Kaur and Singh (2015)**.

Conclusion

On the basis of results it may be concluded that for obtaining optimum growth and yield attributes as well as yield from wheat crop 120 kg nitrogen should be applied with the combination of 6 tones ha^{-1} FYM. The cost of cultivation with the use of organic manure may be comparatively higher but to some extent it will also replenish the deficit nutrients and therefore the soil health will be maintained. The study shows that the application of nitrogen @ 150 kg ha^{-1} is also increase the yield of wheat and equally good with treatment receiving 120 kg nitrogen with the combination of 6 tones ha^{-1} FYM.

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Table.1 Effect of different Nitrogen levels and Farm Yard Manure (FYM) on plant height (cm.) at different growth stages.

Treatments	Plant height (cm.)			
	30 DAT	60 DAS	90 DAS	At harvest
T1	18.85	58.42	76.46	74.34
T2	24.87	63.43	80.13	78.25
T3	25.39	64.88	81.20	80.67
T4	27.23	67.27	83.13	82.45
T5	27.60	68.94	83.87	82.86
T6	27.90	69.88	84.67	83.38
T7	29.76	72.52	88.00	86.75

T8	28.34	71.63	85.67	84.79
SE (m)	1.55	1.41	1.10	1.44
CD(p=0.05)	4.76	4.32	3.37	4.41

Table.2 Effect of different Nitrogen level and Farm Yard Manure (FYM) on number of tillers (m⁻¹ row length) and dry matter accumulation (gm m⁻¹ row length) at different stages.

Treatments	No. of tillers	Dry matter accumulation(gm.)			
	60 DAS	At harvest	30 DAS	60 DAS	At Harvest
T1	53.97	47.76	47.12	283.96	589.92
T2	64.40	61.25	49.19	295.09	608.45
T3	69.78	67.28	50.26	302.43	643.38
T4	76.33	73.59	51.71	319.33	663.13
T5	79.34	77.47	53.14	338.00	707.67
T6	86.09	83.85	56.36	344.38	722.07
T7	93.68	90.78	62.43	373.99	751.75
T8	91.25	88.45	57.35	348.94	743.65

SE (m)	1.76	1.67	47.12	283.96	589.92
CD(p=0.05)	5.40	5.12	49.19	295.09	608.45

Table 3. Effect of different Nitrogen levels and Farm Yard Manure (FYM) on yields (q ha⁻¹) of wheat.

Treatments	Yields (q ha ⁻¹)		
	Grain yield	Straw yield	Biological yield
T1	17.80	27.36	45.16
T2	21.10	32.26	53.36
T3	23.83	35.36	59.193
T4	26.30	38.26	64.56
T5	30.60	42.36	72.96
T6	32.13	46.16	78.29
T7	37.63	50.36	87.99
T8	36.20	48.66	84.86
SE (m)	1.55	2.27	2.227
CD(p=0.05)	4.75	6.95	6.821

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ROLE OF DIGITAL TECHNOLOGY IN MODERN HORTICULTURE - A REVIEW

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Abstract

Digital Agri-Horticulture involves the application of digital technology to integrate agricultural output from the field to the consumer. Digital advancements can help developing countries overcome global poverty and hunger in rural areas more quickly. Digitalization is commonly considered as having the potential to increase agricultural output and sustainability. However, the digitalization of agricultural innovation systems is likely to have broader ramifications. The horticulture sector in India is experiencing significant transformation driven by technological advancements, sustainability trends, and evolving consumer preferences. These trends are contributing to increased productivity, efficiency and market reach positioning Indian horticulture for growth and innovation in the coming years. Agricultural genome makes use of big data generated from computer assisted genomic mapping to determine edits to the DNA of living organisms which promise a more accurate way to modify a plant's genetic code to express new traits for improving crop production.

Key words: Digital Technology adoption, Urbanization, Precision Farming etc.

Digital technology is rapidly transforming horticulture sector in India, bringing innovations that enhance productivity, efficiency and sustainability. Given the sector's importance in India's economy and its challenges—such as climate variability, pest management, and supply chain inefficiencies—digital tools are playing a crucial role in modernizing horticultural practices.

Digital technology is revolutionizing horticulture by introducing innovative tools and systems that enhance efficiency and productivity. Through precision agriculture, drones, IoT sensors, and data analytics, horticulturists can now monitor plant health, optimize resource use, and manage crops with unprecedented accuracy. These advancements enable better decision-making, improved yield, and more sustainable practices, ultimately transforming traditional horticultural methods into a data-driven and highly efficient industry.

Applications of technology farmers in India have a very small landholding and they are unable to sustain the cost of buying the seeds and other essentials. Here, artificial intelligence for predicting the weather at a local level guides farmers to use sustainable techniques (Tanhaet al, 2020).



Over view of Horticulture in India: Horticulture in India is a vital sector within agriculture, focusing on the cultivation of fruits, vegetables, flowers, and medicinal plants. It plays

a key role in the economy by enhancing food security, providing nutrition, and generating employment. Horticulture in India is a dynamic and evolving sector, driven by technological advancements and supportive policies, with significant potential for future growth and development.

- **Diverse Production:** India is a leading producer of fruits like mangoes, bananas, and oranges; vegetables such as potatoes, tomatoes, and onions; and flowers, including marigolds and roses.
- **Economic Impact:** The sector contributes significantly to the GDP, with horticulture accounting for about 30% of the total agricultural output.
- **Fruit Production:** Prominent states include Maharashtra, Himachal Pradesh, Uttar Pradesh, and Tamil Nadu. **Vegetable Production:** Major producers are West Bengal, Uttar Pradesh, Punjab, and Bihar. **Flower Cultivation:** Karnataka, Maharashtra, and Andhra Pradesh are key flower-growing regions.
- **Support Programs:** Initiatives like the National Horticulture Mission (NHM) and Pradhan Mantri Krishi Sinchai Yojana (PMKSY) provide subsidies, infrastructure support, and technology integration. **Research and Development:** Investments in R&D focus on improving crop varieties, pest management, and advanced cultivation techniques.
- **Modern Techniques:** Adoption of precision farming, greenhouse cultivation, and advanced irrigation systems is on the rise. **Digital Tools:** The use of digital technologies for monitoring, data analytics, and market linkages is increasing.
- **Sustainability:** There is a growing focus on sustainable and organic farming practices. **Export Potential:** Expanding export markets and improving global competitiveness are key growth areas.



Prospects for Digital technology of Horticulture in India: The horticulture sector in India is poised for significant growth, driven by technological advancements, supportive government policies, and increasing domestic and international demand. By leveraging these opportunities and addressing challenges, the sector can enhance its contribution to the economy, improve food security, and offer sustainable livelihood options for farmers.

- **International Markets:** India's horticultural products have increasing potential in international markets due to quality improvements and competitive pricing.
- **Trade Agreements:** Bilateral trade agreements and participation in global trade platforms can enhance export opportunities.
- **Cold Storage and Logistics:** Investments in cold storage facilities and improved logistics will reduce post-harvest losses and enhance market access.
- **Market Linkages:** Enhanced market infrastructure and digital platforms can improve farmers' access to markets and fair pricing.
- **Agri-Tech Startups:** The rise of agri-tech startups is bringing innovation to the sector, offering solutions for farm management, supply chain efficiency, and market access.
- **Value Addition:** Opportunities for value addition through processing and packaging can enhance profitability and create new market segments.
- **Capacity Building:** Training programs and educational initiatives can equip farmers with the knowledge and skills needed to

adopt new technologies and practices.

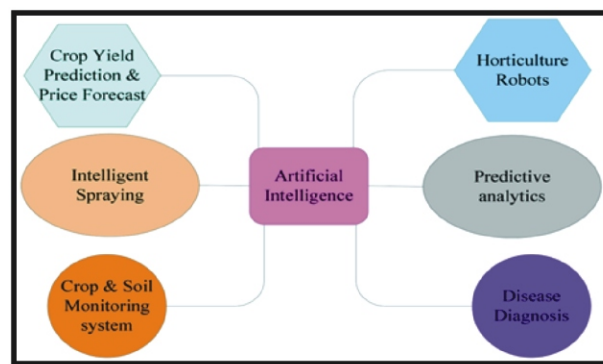
Impact of Digital Technology in Horticulture: Digital technology is revolutionizing horticulture by enhancing crop management, improving resource utilization, and streamlining supply chains. As these technologies continue to evolve and become more accessible, they hold the potential to significantly increase productivity, sustainability, and profitability in the horticulture sector. Embracing these advancements will be crucial for addressing future challenges and meeting the growing demands of the global market. Digital technology is having a transformative impact on the horticulture sector, reshaping how crops are managed, monitored, and marketed. Microsoft developed an artificial intelligence sowing App that uses machine learning and business intelligence from the Microsoft Cortana Intelligence Suite. It uses powerful cloud-based predictive analytics to empower farmers with crucial information and insights to reduce crop failure, increase yield, reduce stress and make better income (Diksha, 2020).

Recent trend of Horticulture in India: The horticulture sector in India is experiencing significant transformation driven by technological advancements, sustainability trends, and evolving consumer preferences. These trends are contributing to increased productivity, efficiency, and market reach, positioning Indian horticulture for growth and innovation in the coming years. Embracing these trends will be crucial for meeting future demands and ensuring the sector's continued development and success. Recent trends in horticulture in India reflect a dynamic sector evolving with advancements in technology, changing consumer preferences, and government initiatives.

Artificial intelligence is a computer science branch with many applications in different fields (Vinod and Anand, 2020). It learns how to program computers to behave intelligently. It has to do with a job similar to using computers to understand human intelligence.

The global market for Artificial Intelligence (AI) in Agriculture is valued at 240 million USD in 2017 and is expected to reach 790 million USD by the end of 2023, growing at a CAGR of 21.8%. The

market for crop monitoring accounted for more than 35% of the global revenue in 2016 and during the forecast period AI-guided drone is expected to be the fastest growing solution. With the help of precision agriculture, these technologies enable farmers to increase yields while utilizing the fewest resources possible and minimizing their total environmental effect. (Aceto *et al.* 2019)



These emerging technologies in farming and agriculture pave the way for more opportunities. The agro-tech start-ups and traditional farmers are also using the latest solutions and trends to improve production in the food value chain. It includes the adoption of new technologies such as cloud-based solutions and other relevant advanced agricultural management techniques to increase farmer efficiency and produce more crops. Increased production, increased investment, diversification of the sector, use of modern techniques, development of horticulture and floriculture, rising export volume, and growth of the food processing industry are emerging trends in the agricultural sector that are quite prominent in the post-liberalization era. (Mockel 2015)

Digital Agri- horticulture-Requirement of the present time: Remote sensing data on soil conditions can help farmers manage their crop. Mobile phones lower the cost of information and improve farmers' access to markets and financial assistance.

Farmers, investors and entrepreneurs can use digital technology to improve efficiency of food production and consumption in India. From precision farming to a more efficient food supply chain, technology has the potential to bring major economic, social and environmental benefits. Digital agriculture involves the application of digital technology to integrate agricultural

production from the paddock to the costumer. Agricultural industries can benefit from these technologies by more tools and information to make better decisions and increase productivity. In rural areas of developing countries where majority of people rely on agriculture for their living, digital technology can assist for overcoming global poverty and hunger more quickly. In digital agriculture, farmers use mobile phones and other technologies that could revolutionize for the communities to secure and improve their livelihoods. It is required more productive, efficient, sustainable, inclusive, transparent and resilient food systems for achieving the UN Sustainable Development Goal of a 'world with zero hunger' by 2030.

Indoor vertical farming, automation and robotics, livestock technology, modern greenhouse practices, precision agriculture and artificial intelligence and block chain have been all major technological advancements in the space. Indoor vertical farming has the potential to increase crop yields, overcome land constraints and shorten supply chain distances. Vertical farms use up to 70% less water than traditional farms. Mobile phones are at the top of the list of digital technologies revolutionizing agriculture. Compared to other recent technologies, they have the highest adoption rates. Two thirds of the world's population, or almost 5.2 billion people, were active mobile phone users as of 2019. Mobile internet is also on the increase, with 49% of the global population using internet services on a mobile device. Only 9% of the world's population lives beyond the service area of a mobile network. Mobile phones have transformed the life of many rural people, particularly small-scale farmers. Farmers may access solutions, such as advisory services that offer ideas on raising outputs, keeping livestock healthy and up-to-date weather information even if they do not have access to mobile internet. Farmers may even access wider choice of high-tech solutions via smart phone applications which can diagnose ailing crops and recommend remedies for many types of pests, diseases and nutrient deficiencies.

Precision agriculture technologies are transforming the face of modern farming. Digital advancements such as wireless communication,

data analytics, and data-driven genome editing, are rapidly being applied in agriculture as they provide more accuracy in decision making and practice. Farm equipment is connected to software platforms that track on-farm data and enable analysis of soil and climate conditions. Agricultural genome makes use of big data generated from computer assisted genomic mapping to determine edits to the DNA of living organisms which promise a more accurate way to modify a plant's genetic code to express new traits for improving crop production.

Digitalization of Indian agriculture includes horticulture: The Government of India is running programs to make agriculture digital, smart, and increase farmer income. These programs include the use of mobile apps and electronics, sensors, the Internet of Things (IoT), data collection, and data analysis tools. The NITI Aayog predicted that AI in agriculture would be worth \$2.6 billion by 2025. AI can help farmers increase yield by helping them choose better crops, hybrid seeds, and farming techniques that use resources efficiently. AgriStack is being developed as a Digital Public Infrastructure (DPI) that will make agricultural data accessible to the public and private sectors. This will allow for the creation of services and solutions. (Lindblom *et al.* 2017)

The report on doubling farmers' income by 2022 advocates for the adoption of digital technologies in agricultural practices it will help in boosting farmers' income. To achieve the vision of the Self-Reliant India Movement and Sustainable Development Goals (SDGs), the transformation of traditional agriculture into digital agriculture is imperative. Farmers are the primary stakeholders in the food production and supply chain as producers, so it will be difficult to achieve and sustain food security without ensuring farmers' well-being and satisfaction.

Thus digitalization is shifting the agriculture policy from direct intervention to information-based governance, which will increase the policy outcomes and ultimately secure the trust of farming communities and will maximize their satisfaction (Ehlers *et al.* 2021).

Some of the recent trends in agricultural technology

Agricultural Drone Technology: Drones are frequently utilized in healthcare delivery, disaster relief, and agriculture to enhance crop growth, maintenance, and cultivation techniques. These aerial transporters, for instance, are employed to monitor crop conditions and carry out improved fertilization plans for higher harvests. Hovering robots are even available to farmers, who may use them to survey vast regions and collect data to improve their understanding of their fields. Drone use in agriculture has made it possible to remotely monitor animals and crops more often and affordably. Additionally, it aids in analyzing field conditions and selecting the proper fertilizers, nutrients, and pesticides.



Diversification of Agriculture: The agricultural sector produces crops such as fruits, vegetables, spices, cashews, areca nuts, coconuts, and floral items such as flowers, orchids, and so on. With the rising demand for these items, there is enormous opportunity for manufacturing and commerce. This demonstrates how the agricultural industry is being changed into a dynamic and commercial sector by moving the mix of conventional agricultural goods toward better quality items, with a great potential for increasing production rates. Changes in technology or consumer demand, commerce or government policy, transportation, irrigation, and other infrastructural innovations all contribute to agricultural diversification.

Increasing Trend in Horticulture Production: The availability of diverse physiographic, climatic, and soil characteristics enables India to grow various horticulture crops. It includes fruits, vegetables, spices, cashew,

coconut, cocoa, areca etc. The total horticulture production in FY22 is estimated at 342.333 million tonnes which is an increase of about 7.03 million tonnes (2.10% increase) from 2020-21.

Development of Agriculture in Backward Areas: In the post-green revolution era, new agricultural techniques, research, and technology were largely focused on growing particular food grains, such as wheat and rice. However, as a result of the wave of liberalization and rising demand for agricultural exports, numerous new agricultural businesses have become favorable and profitable. Dry land farming has been established in some agriculturally backward locations where there is no irrigation infrastructure and access to fewer resources. Other enterprises such as horticulture, floriculture, animal husbandry, fishing, and so on were also promoted. Various sophisticated procedures have been introduced in backward areas to help with development.

Aerial Imaging: Aerial imaging use geographic information system (GIS) technology to assess the feasibility of irrigation projects and their influence on land degradation, erosion, and drainage. This technology's graphics enable analysis of a single plant's leaf. To safeguard crops from environmental risks, these visualizations are actively employed to identify pests and illnesses. It primarily assists farmers in monitoring agricultural soil conditions and is especially valuable during the summer months when water is scarce.

Hydroponics and Vertical Farming: The goal of hydroponic farming is to produce crops with greater yields, texture, and flavor while using less water. Hydroponically grown plants do not require substantial root systems, which enables them to devote more energy to the creation of leaves and fruits. These plants develop more quickly and have greater defenses against pests and other illnesses as a result of indoor culture. In terms of sustainability, vertical farming enables farms to be situated close to or inside of densely populated regions, reducing the need for transportation and any harmful emissions. Growing crops in urban settings is possible because to vertical farming, which also helps to readily make fresh food available. Compared to traditional farming

practices, this farming dramatically decreases the amount of land space needed to cultivate crops.

IoT in Agriculture: – IoT assists agriculture by putting numerous sensors in farming facilities. These sensors are used to keep an eye on things like crop health, temperature, humidity, light, and soil moisture (Poppe *et al.* 2017 and Rotz *et al.* 2019) The following are some of the key IoT applications in agriculture:

- The gathering of data to analyze the operation of the farm is facilitated by a variety of farm sensors, including autonomous cars, wearables, button cameras, robots, control systems, etc.
- Use of drones for field analysis, irrigation, monitoring, and crop health evaluation from the air and on the ground.
- Using techniques to anticipate weather, soil conditions, humidity, and other natural disasters.



Conclusion: Agri- Horticulture is an important sector of the country. It is one of the market-driven industries that employ a large segment of the country's population. It's made up of a series of complex interconnected processes. It should be organised into efficient stages to ensure a good yield. A triangle formed by the farmer, technology and the service and consulting concept will determine the success of a given product. Agriculture like other areas in the economy will be digitized in the future. Government should spend time and financial resources for socializing the digitization benefits. Inadequate connectivity in rural areas, high service charges, and a lack of basic computer literacy and understanding are obstacles for the quick development of e-agriculture. Physical infrastructure, power, broadband and transportation all require substantial investment.

The future of Indian agriculture seems bright and promising with the advent of new technologies. The government has increased its focus on the sector, implementing various policies and initiatives to boost productivity and growth. India's vast and diverse agricultural landscape, coupled with advancements in technology, provides immense opportunities for farmers to harness their potential and increase yield.

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“CURRENT APPLICATIONS OF TRICHODERMA IN AGRICULTURE: BIOCONTROL OF FUNGAL PATHOGENS AND ENHANCEMENT OF PLANT GROWTH”

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Abstract

Filamentous fungi of the genus *Trichoderma*, commonly found in the rhizosphere, are a prevalent component of various soil ecosystem mycobiomes and are known for their ability to colonize plant roots. Understanding *Trichoderma*'s characteristics, including its metabolic activity and interactions with plants and other microorganisms, is crucial for its effective application in agriculture. Interest in *Trichoderma* is growing due to its direct and indirect biocontrol capabilities against a wide spectrum of soil-borne phytopathogens. These fungi employ a range of complex mechanisms, such as mycoparasitism, degradation of pathogen cell walls, competition for nutrients and space, and activation of plant defence responses. Given the continuous threat posed to plants by various pathogens, particularly filamentous fungi, and the increasing resistance of these pathogens to chemical pesticides, there is a pressing need to develop alternative biological protection strategies. Among non-pathogenic microorganisms, *Trichoderma* stands out as a promising candidate for sustainable agricultural practices due to its extensive biofertilization and bio stimulatory properties. Most *Trichoderma* species function as plant growth-promoting fungi, capable of producing phytohormones and the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase. This review consolidates current knowledge on the role of *Trichoderma*, emphasizing its significance in promoting plant growth and its effectiveness in the biocontrol of fungal phytopathogens.

Keywords: Biological control, Phytohormones, Mycoparasitism, Competition, Antimicrobial metabolites, Induction of plant resistance

Introduction

Plant diseases significantly impact agricultural resources, causing a notable reduction in global food production, which is estimated to be between 10% and 40% annually, depending on the source [1]. Soil-borne pathogens are the main culprits behind these losses, with fungi being the most prevalent group responsible for plant diseases, destroying up to one-third of all crops every year [3]. According to the Food and Agriculture Organization of the United Nations (FAO), fungal infections most commonly affect the five major global crops: rice, wheat, corn, potatoes,

and soybeans [2]. Currently, over 19,000 fungal species are known to cause crop diseases worldwide [4]. The majority of these fungal pathogens belong to the Ascomycota and Basidiomycota phyla, with significant threats posed by genera such as *Cladosporium*, *Botrytis*, *Alternaria*, *Aspergillus*, *Verticillium*, *Pythium*, *Fusarium* (Ascomycota), and *Rhizoctonia* (Basidiomycota) [5]. The widespread use of chemical pesticides has put immense pressure on agricultural environments in recent decades, as they remain the most common method for combating fungal pathogens [8]. Although these

chemical products are highly effective, there are growing concerns about their safety and impact on the environment, as well as on human and animal health [6]. Overuse of chemical pesticides has led to increased resistance among pathogens, along with soil and groundwater contamination. Additionally, these pesticides can harm non-target organisms, including beneficial insects like pollinators, disrupt soil microbiomes, and negatively impact the health of terrestrial and aquatic ecosystems [5].

To mitigate the environmental damage caused by chemical fungicides, various sustainable agricultural practices have been developed, including Integrated Pest Management (IPM) and organic farming [7]. One effective strategy is the use of Biological Control Agents (BCAs), which utilize living microorganisms, their metabolites, or natural products to control plant pathogens [16]. In recent decades, significant efforts have focused on assessing the effectiveness of non-pathogenic bacteria and fungi for commercialization as BCAs [20]. As a result, numerous bacterial and fungal strains have been successfully employed as BCAs, such as *Pseudomonas*, *Bacillus*, *Streptomyces*, *Trichoderma*, *Glomus mosseae*, *Gliocladium virens*, *Pythium oligandrum*, and *Beauveria bassiana*. These microorganisms effectively manage soil-borne diseases caused by fungi, oomycetes, bacteria, and nematodes in valuable crops [9]. Incorporating microbiological technologies based on microorganisms with bio stimulatory properties into plant cultivation is another essential aspect of sustainable agricultural practices [22]. These approaches align with the strategic objectives outlined in the European Green Deal (EGD) and the EU Biodiversity Strategy for 2030, which emphasize the importance of promoting agroecology, enhancing agricultural biological, and expanding areas dedicated to ecological production systems [23]. Among filamentous fungi, many BCAs belong to the Ascomycota phylum, primarily represented by species from the *Trichoderma* genus [24]. Numerous studies have shown the advantageous properties of non-pathogenic *Trichoderma* strains, making them valuable for plant protection, bio stimulation, and biofertilization [4,]. The successful application of *Trichoderma* in agriculture depends on its metabolic activity and

interactions with plants and other microorganisms. These fungi are effective at colonizing the rhizosphere, rhizoplane, and plant roots, producing various metabolites with antimicrobial properties (such as cell wall-degrading enzymes, antibiotics, and volatile and non-volatile compounds) and bio stimulatory effects (including phytohormones and Phyto regulators). Moreover, *Trichoderma* is known for its strong root colonization capabilities and interactions not only with pathogenic microorganisms but also with the broader soil microbiome [24,26]. This review highlights the specific attributes of *Trichoderma*, focusing on identifying strains with optimal characteristics for commercialization as biocontrol agents against fungal phytopathogens and as bio stimulants in specific crop production system.

“Traits of *Trichoderma* that Enable its Agricultural Application”

Trichoderma is a genus of predominantly asexual filamentous fungi (with *Hypocrea* as their teleomorphic form) that are commonly found worldwide, typically colonizing decaying wood and other types of organic plant matter [27]. These fungi are a major component of the mycobiomes in various soil ecosystems, including farmland, forests, prairies, deserts, and salt marshes, across all climatic zones, from temperate and tropical regions to Antarctica and the tundra [4,28]. Classified as cosmopolitan, saprotrophic fungi, *Trichoderma* species often live as endophytes in woody plants [28]. The genus now includes over 300 species that have been molecularly and morphologically characterized, although many species have yet to be formally described [32,33,34]. *Trichoderma* species are effective as biocontrol agents due to their rapid growth, ability to utilize a wide range of substrates, and resistance to various toxic substances, including fungicides (e.g., azoxystrobin, 3,4-dichloroaniline, and trifloxystrobin), herbicides, and organic pollutants [28,35,36,37,38]. These fungi also produce enzymes involved in cellulose and lignin degradation, which can break down toxic contaminants [36,38]. For instance, *T. viride* is known to degrade trinitrotoluene (TNT), and *T. inhamatum* can reduce hexavalent chromium [39,40]. Additionally, *Trichoderma* adapts well to

environmental changes and produces large quantities of conidia and chlamydospores [29,11,2]. Recent studies have shown that *Trichoderma* can grow across a wider temperature range than previously thought, with optimal temperatures for metabolite production crucial for plant interactions. While the highest saprotrophic activity occurs between 15 and 21 °C [13,24], some strains, like DEMTkZ3A0, have shown optimal auxin and gibberellin synthesis at 12 °C, along with high ACC deaminase activity [26]. On Potato Dextrose Agar (PDA), *Trichoderma* forms a white or transparent mycelium, with colonies that may appear green-yellow or reddish depending on sporulation [21]. The fungi are identified by their multi-branched, pyramid-shaped conidiophores, asymmetrically bent phialides, and conidia that range from colourless to shades of green, grey, or brown [29,35,31,40]. Some species also produce a distinctive sweet or coconut-like odour [46]. *Trichoderma* is not only widespread and easy to isolate but also can be effectively cultivated on various substrates under controlled conditions and stored for long periods without losing viability or effectiveness.



Fig 1 : Growth of *Trichoderma* on PDA Media & Rice and storage of *Trichoderma* in powder form.

"*Trichoderma*'s Biocontrol Capabilities against Fungal Plant Pathogens"

Trichoderma fungi employ a range of complex direct and indirect mechanisms to combat fungal pathogens, which often work together in the biocontrol process [4]. Direct actions against pathogens include the production of cell wall-degrading enzymes (CWDEs), the synthesis

of antibiotics, competition for resources such as space and essential nutrients (primarily carbon, nitrogen, and iron), and the establishment of a parasitic relationship with the pathogen. Conversely, *Trichoderma* can indirectly trigger local or systemic plant resistance by releasing products (elicitors) from the cell walls of both the plant host (Endo elicitors) and the invading microorganism (Ex elicitors) [30]. The specific mechanisms involved typically depend on the strain and the nature of the interaction among the antagonist microorganism, the pathogen, and the host plant.

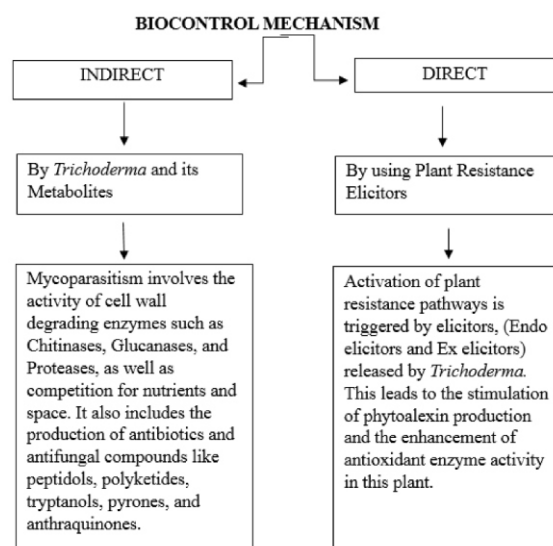


Fig 2: The *Trichoderma* genus employs various biocontrol mechanisms to defend against fungal pathogens

Optimization of Pda Media for *Trichoderma Viride* Growth

The composition of PDA media was optimized by varying concentrations of nutrients such as dextrose, yeast extract, and peptone. Three different media compositions were tested:

1. **Composition 1:** 200 g potato, 15 g dextrose, 6 g yeast extract, 12 g peptone, 8-10 g agar, 500 ml distilled water, pH 5.6.
2. **Composition 2:** 200 g potato, 15 g dextrose, 6 g yeast extract, 15 g peptone, 8-10 g agar, 500 ml distilled water, pH 5.6.
3. **Composition 3:** 200 g potato, 20 g dextrose, 6 g yeast extract, 15 g peptone, 8-10 g agar, 500 ml distilled water, pH 5.6.

Each composition was tested by spreading *Trichoderma viride* and incubating at 28°C for 48

hours.

“Trichoderma As A Biocontrol Agent For Managing Various Plant Pathogenic Organisms”

Numerous *Trichoderma* strains have been developed as effective biocontrol agents for managing plant diseases caused by bacteria, nematodes, and insects [15,16]. Among the over 200 species of plant pathogenic bacteria, *Agrobacterium*, *Pseudomonas*, *Erwinia*, *Ralstonia*, and *Xanthomonas* are the most destructive to crops globally [15]. *Trichoderma* exerts its antibacterial effects primarily through secondary metabolites such as peptaibols, gliotoxin, polyketides, gliovirin, and pyrones [15,16]. For example, *T. pseudoharzianum* and *T. asperelloides* effectively inhibit the bacterial pathogen *Ralstonia solanacearum*, leading to significant damage to the pathogen's cell structure. Additionally, *T. hamatum* produces the volatile metabolite 6PAP, which inhibits *Acidovorax avenae*, *Erutimacarafavora*, and *Xanthomonas campestris* [17]. The endophytic strain *T. longibrachiatum*, isolated from *Dendrobium nobile*, has shown potential in medical applications by producing dendrobine, a compound that enhances immunity and offers therapeutic benefits against cancer and Alzheimer's disease, while also exhibiting strong antibacterial activity [18].

Trichoderma also effectively combats plant-parasitic nematodes (PPNs), which pose a significant threat to agriculture, causing an estimated 12% crop damage worldwide. *Trichoderma* controls nematodes through direct parasitism and by producing hydrolytic enzymes and secondary metabolites that degrade nematode cuticles. *T. harzianum* has been shown to reduce root-knot nematode damage in tomatoes by penetrating nematode matrices and decreasing egg hatching, while also boosting plant defence enzyme activities. *T. asperellum* and *T. harzianum* have been reported to inhibit nematode penetration in soybeans through nematicidal compounds.

Recent research has also highlighted *Trichoderma*'s role in protecting plants from insect pests like aphids, thrips, moths, and caterpillars. *Trichoderma* employs various antagonistic mechanisms, including parasitism and the

production of insecticidal compounds, antifeedants, and repellents. It also enhances plant defence mechanisms against these pests. For instance, *T. longibrachiatum* affects the development of *Leucinodes orbonalis* in eggplants, and *T. gamsii* shows intense parasitism of *Delia radicum* larvae. Additionally, *T. harzianum*, *T. asperellum*, and *T. hamatum* have demonstrated potential against *Cetarovacuna lanigera*, a significant pest of sugarcane.

Conclusion

The interaction between *Trichoderma* fungi, plants, and pathogens is highly dynamic and dependent on multiple factors. Understanding the detailed mechanisms by which *Trichoderma* acts against plants and pathogens can greatly enhance its effectiveness. *Trichoderma* employs a range of direct and indirect biocontrol strategies to combat both biotic stresses (such as pathogens and pests) and abiotic stresses (like adverse environmental conditions).

Recent advances have highlighted the exceptional capabilities of *Trichoderma*, paving the way for the development of biopreparations that harness these strains' comprehensive benefits for plants. These preparations hold promise for use in organic farming, where they can potentially provide full protection against plant diseases without relying on chemical pesticides. Furthermore, *Trichoderma*'s resistance to pesticides allows it to be combined with low concentrations of chemical pesticides, including newly formulated ones. Additionally, *Trichoderma* could play a key role in new phytoremediation technologies due to its tolerance to various toxic chemicals, thus enhancing plant stress tolerance in contaminated environments. These applications align with sustainable agricultural practices.

In the near future, efforts will focus on enhancing the efficacy and reliability of *Trichoderma* preparations by improving their competitiveness in the rhizosphere and rhizoplane. This can be achieved through strategies like ensuring robust and stable colonization in these areas and combining *Trichoderma* with supportive microorganisms that enhance its positive effects. For example, volatile compounds from certain bacteria can

significantly boost the antimicrobial and antifungal activities of *T. virens* and *T. harzianum*. *Trichoderma* fungi have become a valuable model for studying microbial interactions with plants, particularly through effector-like molecules. Research has identified various plant interaction effectors from *Trichoderma*, including proteins (such as cerato-platanins and hydrophobins), secondary metabolites (like lactones and terpenes), and small non-coding RNAs. These effectors play a role in establishing beneficial symbiotic relationships with plants and could also shed light on potential negative impacts on agriculture. One key aspect of *Trichoderma*'s influence is its ability to release N-acetylglucosamine (GlcNAc) as a universal signalling substance through chitinolytic activity. This process is critical for the effective degradation of fungal cell walls and successful pathogen attack. The main challenge lies in developing advanced, cost-effective, and efficient methods for detecting and evaluating *Trichoderma* antagonists. This includes combining various modes of action and assessing their impact comprehensively. Research will also focus on accurately estimating the risk, toxicity, and ecotoxicity of *Trichoderma*-based biocontrol agents in both controlled and natural environments before they are commercially introduced. Addressing societal concerns about introducing new microorganisms with antifungal and antibacterial properties into the environment is also crucial.

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AONLA (*EMBLICA OFFICINALIS* GAERTN): AN OVERVIEW OF ITS ADVANCEMENTS, MANUFACTURING, AND VARIED APPLICATIONS

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Abstract

Aonla (*Embllica officinalis* Gaertn), also known as Indian gooseberry and part of the Euphorbiaceae family, is one of the oldest indigenous fruit tree species, widely distributed due to its adaptability to various edaphic and climatic conditions. This fruit is highly valued for its nutritional, therapeutic, postharvest, and industrial uses. Ancient texts have documented the pharmaceutical properties of aonla, either alone or in combination with other ingredients. To enhance and fully utilize the current genetic resources of aonla, it is essential to understand studies related to its uses, origin, diversity, as well as its characterization, evaluation, conservation, taxonomy, systematics, phenology, floral biology, and pollination. Alongside the plant's basic biology, knowledge of agricultural techniques, propagation methods, canopy architecture, physiological disorders, pest and disease management, and other practices are crucial for conserving aonla germplasm and improving its production. This review article aims to cover these aspects in detail concerning aonla.

Key words: Biology, Germplasm, *Embllica officinalis*, Indian gooseberry

Introduction

Aonla (*Embllica officinalis* Gaertn), commonly known as Indian gooseberry, is a significant fruit crop originating from India and is cultivated across various regions of the country under different agro-climatic conditions. Revered as a sacred tree and referred to as Amritphal in ancient texts, aonla trees are also found in the natural forests of countries like Cuba, the USA, Pakistan, Sri Lanka, Malaysia, China, Java, and the West Indies. It is widely used in Ayurvedic medicine for preparing formulations like Triphala and Chyawanprash. Due to its resilience, high yield, nutritional and medicinal properties, and versatility for producing various value-added

products, aonla has gained prominence as a vital fruit in the 21st century (Pathak 2003). The fruit is beneficial for treating multiple ailments and can be processed into a variety of products. Aonla powder, derived from the fruit, is more effective than synthetic vitamin C in addressing deficiencies. It is cultivated over an estimated area of 50,000 hectares, with an annual production of 1.5 lakh tonnes (Pathak *et al.* 2003).

Origin and distribution, soil and climate, area and production

In India, the domestication of aonla began in Varanasi, Uttar Pradesh, initiated by the Maharaja of Kashi. A superior variety, Banarasi, was selected from the wild aonla trees that were

abundant in the nearby Vindhyan hills. Records indicate that its cultivation in the Pratapgarh district of Uttar Pradesh dates back to 1881-82. The district's ruler, who was unwell, was advised to consume aonla fruits regularly. The fruits brought from Varanasi were called 'Banarasi,' while those from Gujarat were initially named Francis and later called Hathijhool due to their drooping branches. A seedling of Banarasi with flat fruits was named Chakla, which is now known as Chakaiya. These various introductions significantly contributed to the development of the high-yielding cultivars found today in Pratapgarh, Uttar Pradesh.

Aonla is commercially cultivated in several states across India, including Uttar Pradesh, Uttarakhand, Gujarat, Maharashtra, Rajasthan, Tamil Nadu, Andhra Pradesh, Karnataka, Bihar, Haryana, Madhya Pradesh, and West Bengal (Pathak 2003). In Uttar Pradesh, it is predominantly grown in districts like Pratapgarh, Varanasi, Sultanpur, Azamgarh, Jaunpur, Rai Bareilly, Agra, and Bareilly, with Pratapgarh being a leading district for commercial aonla cultivation nationwide (Pathak *et al.* 1993). Over the past two decades, there has been a significant expansion of aonla cultivation across the country, particularly on wastelands. This expansion has led to more efficient resource utilization, increased farmer incomes, improved nutritional security, enhanced employment opportunities, and the rehabilitation of wastelands (Singh *et al.* 2014c).

Although aonla is typically classified as a subtropical fruit, it thrives in tropical, arid, and rainfed semi-arid conditions. Naturally growing aonla trees can be found on hills up to an elevation of 1800 meters above sea level (Pathak 2003). In India, the fruit is cultivated from the coastal areas of South India to the foothills of North India. Mature aonla trees are capable of withstanding temperatures ranging from freezing to as high as 48°C. However, they are vulnerable to frost, which can cause significant damage, particularly in the hot, arid regions of western Rajasthan (Pathak *et al.* 2006). Warm temperatures promote the formation of flower buds, while high humidity is necessary for the growth of dormant fruitlets during July and August (Pathak 2003). Sudden temperature fluctuations during flowering and

fruit set can negatively impact fruit production, and prolonged dry periods may lead to excessive fruit drop and delayed fruit growth (Pathak *et al.* 2006). Due to its hardy nature, aonla can be cultivated in both light and heavy soils. Its deep root system, reduced foliage, dormancy period of fertilized fruitlets from April to June, and alignment of fruit growth with periods of moisture availability make it well-suited for arid and semi-arid regions. Aonla can also be grown on marginal, degraded lands and in a range of soil types, including acidic and saline/sodic soils with pH levels up to 9.5, exchangeable sodium percentage (ESP) of 35, and electrical conductivity (ECe) of 6-9 dS/m (Pathak and Pathak 2001).

Importance, uses and medicinal significance

In Ayurveda, aonla has been widely used both as a consumable tonic due to its therapeutic properties and as a powerful rejuvenating agent (Rasayana). The fruit contains a variety of phytochemicals, such as fixed oils, phosphatides, essential oils, tannins, minerals, vitamins, amino acids, fatty acids, glycosides, and more. Previous studies have highlighted the numerous pharmaceutical benefits of *Phyllanthus emblica*, including its antimicrobial, antioxidant, anti-inflammatory, analgesic, antipyretic, adaptogenic, hepatoprotective, antitumor, antiulcerogenic, and immunomodulatory activities, whether in combination with other ingredients or as Indian gooseberry alone (Bajpai and Shukla 1990, Baliga 2012, Chatterjee and Sil 2007). However, the pharmacological effects of aonla are often discussed in the context of Triphala, which is composed of equal parts of three medicinal plants: **Emblica officinalis**, *Terminalia chebula*, and *Terminalia bellerica*. Aonla's antioxidant and free radical scavenging abilities are attributed to the presence of ascorbic acid, tannins, and polyphenolic compounds. Various extracts of aonla and its phytoconstituents have shown antioxidant efficacy against several free radicals, such as 1,1-Diphenyl-2-picrylhydrazyl (DPPH), superoxide, nitric oxide, iron reduction, and 5,5-dimethyl-1-pyrroline-N-oxide. Additionally, the phytochemicals in aonla are known to be effective metal ion chelators, helping to prevent oxidative cascades (Scartezzini *et al.* 2006). The

fruit's nutraceutical and therapeutic values contribute to overall health and vitality (Pathak 2003).

Morphology, flower biology, cytogenetic, pollination and pollinators

Aonla belongs to the family Euphorbiaceae and the order Euphorbiales, and it is classified under the new genus *Emblica* (formerly *Phyllanthus*), which includes about 350 to 500 species, mostly shrubs, with a few herbs and trees. Among the various species of aonla, *E. officinalis* is primarily cultivated (Fig 1). Other related species include *E. acidus* Skeel, or star gooseberry, which is mainly grown for ornamental purposes; *E. myrobalan*, a small to moderately sized deciduous tree; *E. fischeri*, which is suitable for making pickles; and *Phyllanthus indofischeri*, a monoecious tree found in the scrub forests of southern India (Pathak 2003). Crop improvement in aonla largely focuses on selecting desirable traits from the diverse seedling populations of cultivated genotypes. The basic chromosome number of Indian gooseberry is reported to be $2n=26$, while the somatic chromosome number in aonla is $2n=28$. Variants with chromosome numbers ranging from $2n=23$ to 104 have also been observed.

The aonla tree exhibits a phyllanthoid branching pattern with two types of shoots: determinate (short shoots) and indeterminate (long shoots). Indeterminate shoots grow longer and continue to produce new growth throughout the season, while determinate shoots emerge at the nodes of indeterminate shoots, with 3 to 5 appearing at each node depending on the cultivar (Bajpai and Shukla 1990, Pathak 2003). Flowering occurs on these determinate shoots from February to March, but in South India, it happens twice a year—in February-March and June-July. Flowers develop in the axils of the leaves on determinate shoots as axillary cymes. The basal cymes consist of male flowers, followed by each node having a cyme with one central female flower (rarely two) and several lateral male flowers (Pathak *et al.* 2006). A typical flower contains a perianth and either an androecium or gynoecium. The number of perianth segments ranges from 5 to 7, with 6 being the most common. Bajpai and Shukla (1990) reported a male-to-female flower

ratio of 307.9:1 and 197:1 over two consecutive years, indicating significant variability in sex expression. Female flowers open gradually over 72 hours, and the stigma becomes receptive on the third day of anthesis, remaining receptive for an additional 48 hours, aligning with the maturation of the embryo sac (Pathak and Pathak 1993). Male flower anthesis occurs between 16:00-17:00 in the Banarasi cultivar and between 08:30-11:00 and 15:30-18:30 in the Chakaiya cultivar. Pollen grain dehiscence coincides with male flower anthesis, and most pollen grains are fertile (Pathak *et al.* 2006). Low fruit set and retention are attributed to pollination failure and low sex ratios (Alleemullah and Ram 1990). Pathak (2003) observed self-incompatibility in aonla during early studies on flowering and fruit set. The number of female flowers ranges from 2 to 8, with NA-6 having the lowest sex ratio, followed by NA-7, Kanchan, and Chakaiya, while NA-9, Banarasi, and Krishna have higher sex ratios. Aonla hybrids such as Chakaiya $\times$ Francis, NA-7 $\times$ Krishna, Banarasi $\times$ NA-6, and Kanchan $\times$ NA-6 shows better fruit retention and are recommended for commercial cultivation, suggesting that poor fruit set may be due to self-incompatibility in some cultivars (Pathak and Srivastava, 1994; Singh *et al.* 1998). The high percentage of staminate flowers is another factor contributing to poor fruit set. Initial fruit set ranges from 12 to 18% but can be improved through hand pollination (Bajpai and Shukla 1990). Although fertilization is completed within 36 hours after pollination, the embryo remains dormant throughout the summer and begins to swell with the onset of the monsoon. The flowering period is more influenced by day length than temperature.

Genetic resources and varietal wealth-

A wide range of variability in aonla has been reported, especially in regions such as Uttar Pradesh, Uttarakhand, Bihar, Chhattisgarh, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Rajasthan, Himachal Pradesh, and the northeastern region of India (Pandey *et al.* 2013, Singh *et al.* 2014c, 2016, Shukla *et al.* 2005, Pathak 2003). Due to the predominance of seedling propagation, India has a rich genetic diversity of cultivated and wild aonla varieties, particularly in the northeast, which can be leveraged in breeding

programs to enhance the resilience of new cultivars to adverse conditions (Singh *et al.* 2014c). The key traits for germplasm collection include large fruit size, low fiber content, and resistance to frost, rust, internal fruit necrosis, and insect pests (Pathak, 2003). Systematic characterization of germplasm, such as the descriptors developed at Narendra Dev University of Agriculture & Technology, Faizabad, has revealed a wide range of variation in different traits (Pathak *et al.* 1993). Similar findings have been reported by Singh *et al.* (2014a), Hiwale (2015), and Bakshi *et al.* (2015) in aonla germplasm studies. Conservation efforts for aonla germplasm are being undertaken in field gene banks at various ICAR Institutes and State Agricultural Universities (SAUs).

Systematic efforts to improve aonla have been made through selection processes (Pathak *et al.* 2006). After yield data and fruit quality were stabilized, one genotype, BSR-1, demonstrated a high yield potential of 43.05 t/ha and was recommended for commercial cultivation under both irrigated and rainfed conditions in Tamil Nadu. Anand Agricultural University in Anand developed the varieties Anand 1, Anand 2, and Anand 3, which were selected from seedling variability available in Gujarat (Singh *et al.* 2014c). From diverse collections at NDUAT, Faizabad, varieties like NA-4 (Kanchan), NA-5 (Krishna), NA-6, NA-7 (Neelam), NA-9, and NA-10 showed promising results and were later released for commercial cultivation (Pathak 2003). Laxmi-52, known for its large fruit, was released by CISH, Lucknow. A clonal selection from a superior tree found in collections at CHES, Godhra, was named Goma Aishwarya (Hiwale 2015). Among these, NA-7 has become a leading cultivar, occupying the largest area under aonla cultivation in the country (Pathak 2003, Singh *et al.* 2014c, 2015).

Biotechnology-

Unfortunately, traditional breeding methods have been unable to solve issues such as leaf rust, wilt, anthracnose, and pests due to various challenges, including the small size of the flowers, variations in chromosome numbers, complex taxonomy, and the highly heterozygous nature of the plant. Therefore, genetic improvement for these traits may be achievable through genetic

engineering. In this context, Thilaga *et al.* (2013) developed a straightforward, single-step protocol for inducing high-frequency somatic embryogenesis from in vitro juvenile leaf tissues of aonla, which can be used to create transgenic populations of the plant. Warude *et al.* (2006) developed markers to identify aonla germplasm.

Plant propagation-

Seed propagation and raising of seedlings:

Aonla seeds typically germinate within two weeks. Seedlings that are six months to one year old are used as rootstocks, onto which scions of desired varieties are patch-budded from May to September for optimal success. Seeds sown in the first week of March in perforated polythene bags (40×15 cm) are usually ready for budding by July, which reduces the process time by about six months and improves nursery management compared to conventional methods. For better germination and healthier seedlings, seeds should be soaked overnight in a 500 ppm GA3 solution (Saroj *et al.* 2001).

Vegetative propagation:

Among various methods of vegetative propagation, patch budding has proven to be the most effective, followed by modified ring budding. For optimal success, budding operations should be conducted from mid-May to mid-August, though it can be extended into September with satisfactory results (Pathak *et al.* 2006). Saroj *et al.* (2001) reported over 90% success with patch budding in perforated polythene bags in irrigated hot arid environments. Softwood grafting on terminal shoots of rootstocks grown in situ for a year or more has also been successful. In situ patch budding is considered the best method for aonla propagation under dryland conditions (Singh *et al.* 2014c, Singh and Singh 2014). The rootstocks used for budding and grafting should be at least 0.5 cm in diameter (Saroj *et al.* 2001). Research on the effects of gypsum and distillery effluent on the chemical composition of shoots and the growth of aonla budlings in pots has been conducted under north Indian conditions (Singh and Gaur 2002, Singh 2007). In contrast, aonla propagation in south India occurs almost 8–10 months of the year using greenhouses and net houses (Pathak 2003).

Micropropagation: -

For rapid multiplication, micropropagation offers an alternative for producing large quantities of planting material. However, in vitro establishment of aonla cultures faces challenges such as oxidative browning and contamination. Using explants, about 80% success in culture establishment has been achieved, though this method slows down bud induction and subsequent proliferation. August to November is the optimal period for bud induction under north Indian conditions, with a success rate of 76.4%, compared to April-June. Shoots that are slightly green and moderately hard (10–15th nodes) yield the highest in vitro bud induction and proliferation, outperforming soft or very hard brown nodal segments, as reported by Mishra and Pathak (2001). After bud induction, determinate shoots develop leaves, but indeterminate shoots are essential for further multiplication. High-frequency shoot proliferation (13.33 shoots/culture) was observed with 4.33 μ M GA3 + 13.9 μ M Kinetin + 342.11 μ M Glutamine. The addition of glutamine (342.11 μ M) addresses the issue of in vitro leaf fall. The study concluded that $\frac{1}{2}$ MS medium with 49.20 μ M IBA and 10.74 μ M NAA is most effective for in vitro rooting of Indian gooseberry (Mishra *et al.* 2006). Callus from mature embryo explants of aonla was cultured on BMS medium with various combinations of 2,4-D, kinetin, and NAA. In some cases, mature explants directly produced embryos from the cotyledons. Secondary embryos formed on BMS + BAP or 2iP (1–4 mg/l) + 5% sucrose. Plantlets transferred to BMS + NAA or IBA (2–4 mg/l) developed roots, but these rooted plants had a high mortality rate during hardening. Various protocols for in vitro regeneration from different explants, such as endosperm, nodal explants, epicotyls, and hypocotyls, have been reported (Hai-Tao *et al.* 2006). Although low-frequency embryogenesis has been documented for this species, reproducibility of these protocols was not confirmed (Menka and Usha 2006).

Agronomy, cultivation, pests and diseases

Planting and orchard establishment: -

To ensure better orchard establishment, pits of 1 m³ (1 m $\times$ 1 m $\times$ 1 m) should be dug in May, spaced 8–10 m apart, and exposed to the sun for about a month. Each pit should then be filled with

soil mixed with 20–25 kg of Farm Yard Manure and treated with chlorpyrifos (Singh *et al.* 2014c). Healthy budded plants should be planted during the rainy season, ideally right after the first rain. Rootstocks can also be grown in situ at suitable distances (8 m $\times$ 8 m or 10 m $\times$ 10 m) for budding with superior clones at the pencil thickness stage to achieve optimal success, especially in semi-arid regions. For in situ budding, plant the rootstock in the prepared pit in June and perform budding 30–45 days later in the field (Singh *et al.* 2014c). To address self-incompatibility issues, it is advisable to plant more than two varieties to ensure proper fruit setting (Pathak *et al.* 2006).

High density planting: -

The study on high-density planting systems showed that the square planting system achieved the highest mean yield per plant at 121.20 kg. However, the double hedgerow system produced the greatest yield per hectare at 284.02 q, while the square system had the lowest yield per hectare at 121.20 q. Under semi-arid conditions, the double hedgerow system increased yield per hectare by 25.62% to 134.34% compared to square, paired, cluster, and hedgerow systems. In rainfed conditions, the double hedgerow, hedgerow, cluster, and paired systems showed yield increases of 134.34%, 121.10%, 97.51%, and 53.77% respectively over the square system (Singh *et al.* 2013b, 2014d). Among the planting systems, the square system provided better physical qualities, whereas the double hedgerow system had the highest levels of chemical attributes, including total soluble solids (TSS), total sugar, vitamin C, and total phenols (Singh and Singh 2007, Singh *et al.* 2007c, 2011, 2014c, 2014d).

Irrigation management: -

Well-established aonla orchards typically do not need irrigation if rainfall and soil moisture are adequate. Irrigation should be avoided during the flowering period (February and March), but it is necessary after applying manures and fertilizers if soil moisture is insufficient. In rainfed conditions, aonla plants irrigated with drip systems every other day, covering 60% of the area, showed improved growth, yield, and quality. Nonetheless, aonla can thrive in rainfed semi-arid conditions without irrigation (Singh *et al.* 2014c). The use of

low-cost earthen dams and a series of check dams has significantly improved soil moisture conservation and fruit crop productivity in Gujarat's semi-arid regions (Meshram *et al.* 2009). Research from NDUAT, Faizabad indicated that alternate drip irrigation at 0.6 CPE and mulching with paddy straw were effective for establishing aonla orchards in sodic soils (Pathak *et al.* 2006).

Training, pruning and canopy management

For effective training of aonla trees, the main branches should start at a height of 0.70 meters above ground. Unwanted branches should be removed through pinching during March-April. In the following years, 4–6 branches should be allowed to grow. Ongoing pruning involves removing dead, infested, broken, weak, or overlapping branches after harvest. Limb breakage has been noted in the NA-7 cultivar due to overbearing and the narrow angle of branches with the main stem, so maintaining a balanced canopy is crucial for this variety (Pathak *et al.* 2006, Singh *et al.* 2014c).

Integrated nutrient management: -

The application of manures and fertilizers depends on soil fertility, plant age, and production levels. For one-year-old aonla plants, the recommended dose is 15 kg of farmyard manure (FYM), 100 g of nitrogen (N), 50 g of phosphorus (P), and 100 g of potassium (K). This dosage should be gradually increased each year up to ten years, after which a constant dose should be maintained (Singh *et al.* 2014c). Various nutrient sources, such as biofertilizers (Azotobacter, Azospirillum, PSB, VAM), FYM, and cakes (neem, mahua, castor, and groundnut) are beneficial for sustainable fruit production (Singh *et al.* 2012a, 2012b). Among organic sources, combinations of FYM with neem cake and CPP or FYM with Azotobacter and VAM have been effective in enhancing soil fertility, microbial and earthworm populations, as well as yield and fruit quality in the semi-arid regions of Western India (Singh *et al.* 2014c, 2014b). Mature trees should receive 1 kg of N, 500 g of P, and 500 g of K annually (Pathak *et al.* 2006). Additionally, spraying micronutrients such as boron (B), zinc (Zn), and copper (Cu) at 0.4% along with lime can help reduce fruit drop and improve fruit quality (Pathak *et al.* 2006).

Soil moisture conservation: -

Using locally available and easily decomposable organic materials such as paddy straw, maize straw, grasses, and husk applied at a thickness of 20 cm after the rainy season has proven beneficial for enhancing soil quality, growth, and yield of NA-7 aonla (Singh *et al.* 2007a). Mulches help conserve soil moisture, regulate soil temperature, and positively impact earthworm and microbial populations, soil fertility, and plant growth and yield (Singh *et al.* 2007b). Aonla leaf litter used as mulch under the canopy effectively retains soil moisture during summer and improves soil properties (Singh *et al.* 2014c). Organic mulches are effective in enhancing physical soil properties, such as porosity and hydraulic conductivity, while reducing electrical conductivity (ECe) and exchangeable sodium percentage (ESP) in the tree basin (Pathak *et al.* 2006). In the 10th year of orchard life, paddy straw mulch resulted in the highest average yield per plant (87.48 kg) compared to the control (76.29 kg) under rainfed conditions in a hot semi-arid ecosystem (Singh *et al.* 2008). The yield with paddy straw mulch was 14.66% higher than the control (Singh *et al.* 2014e). Additionally, paddy straw mulch produced the highest quality fruit, with total soluble solids (TSS) at 9.50° Brix, total sugar at 6.00%, and vitamin C at 510 mg/g, surpassing the control (Singh *et al.* 2010).

Crop diversification: -

Cucurbitaceous vegetables such as bottle gourd, sponge gourd, bitter melon, cucumber, and pumpkin can be successfully cultivated alongside aonla in the rainfed conditions of Gujarat. Economic analysis of aonla-based cropping systems shows that the highest net returns of ₹147,312.80 and ₹1,000,525.00 can be achieved with aonla paired with bottle gourd and pumpkin, respectively, under semi-arid rainfed conditions (Singh *et al.* 2013a, 2014c). According to Hiwale *et al.* (2014), growing aonla with okra yields net returns of ₹72,505 per hectare without negatively affecting the aonla crop. Various intercrops, including okra, bottle gourd, cauliflower, coriander, matricaria, gladiolus, and marigold, can be effectively grown in conjunction with aonla plantations (Pathak *et al.* 2006, Singh *et al.* 2014c, Krishna *et al.* 2018). Among fruit crops, guava and

karonda can serve as successful filler crops in aonla orchards (Pathak *et al.* 2006).

Fruit setting, fruit growth and development:

In North India, aonla trees start shedding their determinate shoots from February to mid-March. New determinate shoots begin to emerge from the node scars left by the previous season's shoots around late February and continue to appear until the first week of April, where they develop blossom buds. Flowering typically occurs after mid-April (Pathak *et al.* 2006). The fruit grows rapidly during the rainy season, from the second half of August to the end of September, completing about 70% of its growth during this period. Consequently, aonla fruit growth follows a double sigmoid curve. Post-fertilization, the embryo remains dormant for approximately 3-4 months, with growth resuming from late July to early August, depending on the monsoon and agroclimatic conditions (Pathak *et al.* 2006 and Singh *et al.* 2014c).

Maturity, harvesting, yield and quality attributes: -

Aonla fruit maturity can be assessed by external signs such as a change in fruit color from greenish to whitish or yellowish green, and a shift in seed color from creamy white to brown. Additionally, physiological maturity is indicated by specific gravity (1.07 to 1.24), fiber content, TSS/acid ratio (5 to 6), the appearance of fiber on the seed cover, and the browning of the seed (Pathak *et al.* 2006, Singh *et al.* 2006). For different cultivars, NA-7, Banarasi, and Agra Bold reach maturity by the last week of October, while Kanchan and Chakaiya are ready for harvest by the last week of November. Anand-1 and Anand-2 mature by the end of November in the semi-arid conditions of Gujarat (Singh *et al.* 2003, 2005, Singh *et al.* 2008b).

Aonla trees begin fruiting in the third year after budding, with commercial yields starting from the fifth year of growth. The physico-chemical characteristics of aonla cultivars have been examined under the rainfed semi-arid conditions of Gujarat (Singh *et al.* 2015, 2014c). Research by Bakshi *et al.* (2015) and Bal *et al.* (2009) has shown significant variation in these attributes across different agro-climatic conditions.

Postharvest handling, storage and value

addition:

Aonla fruits can remain on the tree for up to 30 days after maturity without losing quality (Singh *et al.* 2003). Varieties such as Chakaiya and Anand-2 have a shelf life of about 7 days, while Francis, NA-7, and Banarasi last up to 5 days at ambient temperature after harvest. However, when stored in brine solution, the fruits can last up to 75 days. NA-7, Banarasi, and Agra Bold are ready for harvest by the last week of October, whereas Kanchan and Chakaiya mature by the end of November. Anand-1 and Anand-2 also mature by late November in Gujarat's semi-arid conditions (Singh *et al.* 2003, Singh *et al.* 2005). Chemical treatments and storage in zero-energy cool chambers significantly extend aonla's shelf life (Singh *et al.* 2007, 2010). Among varieties, NA-10, Krishna, and Chakaiya have a shelf life of 10 days, maintaining high vitamin C and a glossy green appearance, while NA-7 can be stored for 6-8 days in north Indian conditions (Singh *et al.* 2005).

The shelf life of aonla fruits can be extended through grading, packaging, and the application of pre and postharvest chemicals and plant hormones. 'A' grade fruits, which are larger (over 4.00 cm in diameter and length), are used for making murabba and candy. 'B' grade fruits, which are smaller, are suited for chavanprash and trifla, while 'C' grade fruits, which are blemished, are utilized for powder and shampoo production (Singh and Singh 2005). In Gujarat's hot semi-arid conditions, aonla fruits treated with 1.5% calcium nitrate or 50 ppm GA3 and stored in perforated polyethylene bags showed the least weight loss (2.12–16.00% and 2.15–16.34%) and spoilage (2.40–15% and 2.50–15.60%), with an 11-day storage life (Singh and Singh 2005). For packaging, wooden crates of 20-25 kg capacity lined with polyethylene or CFB boxes (10 kg capacity) with newspaper liners are most effective for long-distance transport, while local markets use plastic crates lined with newspaper (Singh *et al.* 2008a). Singh and Kumar (1997) compared storage of fully mature aonla fruits under various conditions, finding that modified storage conditions had the least decay loss (26.56%) after 24 days, compared to 48.70% decay in zero-energy chambers. Fruits can also be stored in cold storage at 0-2°C and 85-90% relative humidity for 7-8

days.

Aonla is not typically consumed as a fresh fruit. Instead, it is primarily used in processing industries to make products such as murraba, candy, chutney, toffee, shreds, sauce, pulp, powder, juice, laddu, and supari. It is also utilized in Ayurvedic medicines like chawanprash, trifla, syrup, diabetic powder, and aonla powder, as well as in cosmetics for shampoos, hair oils, and dyes (Pathak *et al.* 2006, Singh *et al.* 2014c).

Insect-pests, diseases and physiological disorders and their management-

Pests and their management:-

The key pests and diseases affecting aonla, along with their recommended control measures, are outlined here. Effective and cost-efficient Integrated Pest Management (IPM) strategies have been formulated to enhance aonla production, taking into account the seasonality and peak periods of these issues.

Key insect pests of aonla include aphids (*Cercophasia emblica*), mealybugs (*Nipaecoccus vastator*), leaf twisters (*Caloptilia acidula*), hairy caterpillars (*Euproctis flava*), shoot gall makers (*Betousa stylophora*), fruit borers (*Virochola isocrates*, *Meridarchis scyroides*), and bark-eating caterpillars (*Inderbela terraonis* Moore) (Pathak *et al.* 2006, Singh *et al.* 2014d). Effective control measures include orchard sanitation for managing bark-eating caterpillars and borers. Foliar application of Dimethoate (0.05%) in the evening every three weeks effectively controls these pests. For optimal pest management, a tri-weekly application of Dimethoate (0.05%), alternated with NSKE (5%) every 10 days from fruit set to fruit development, significantly reduces borer incidence in aonla (Pathak *et al.* 2006, Singh *et al.* 2014c).

Diseases and their management:-

Key diseases affecting aonla include rust (*Ravenaliia emblicae*), anthracnose (*Colletotrichum*, a form of *Glomerella cingulata*), and Penicillium fruit rot (*Penicillium indicum*, *P. oxalicum*, *Aspergillus niger*), which cause significant losses for growers (Singh *et al.* 2010c). Rust can be managed effectively by spraying with wettable sulfur (2%) or Mancozeb 75 WP (0.2%) every 10-12 days starting in early August. To control anthracnose, applying Mancozeb 75 WP

(0.2%) or Copper oxychloride 50 WP (0.3%) along with deep ploughing and proper cultivation practices is effective. Penicillium fruit rot, a postharvest issue, can be managed by removing and destroying infected fruits. Additionally, preharvest sprays with Blitox, Bavistin, or KH₂PO₄ a week before harvest, and postharvest treatments with 1.5% CaCl₂ and GA₃ (200 ppm), help control this disease (Singh *et al.* 2009, Singh *et al.* 2014c).

Physiological disorders:-

Fruit necrosis, a physiological disorder in aonla, is linked to boron deficiency. It begins with browning of the mesocarp and progresses to the epicarp, causing a brownish-black discoloration of the flesh. This issue can be managed by applying three sprays of 0.6% borax at 15-day intervals starting from early September (Pathak *et al.* 2006, Singh *et al.* 2014c). Additionally, growing necrosis-resistant varieties such as NA-7, NA-6, and Chakaiya is recommended (Pathak *et al.* 2006).

Aonla holds significant economic potential for India and thus requires the promotion of cultivars with desirable horticultural characteristics and the expansion of cultivation in arid and semi-arid regions. It is crucial to leverage existing genetic resources through comprehensive surveys and collections for further crop enhancement. Research should focus on the inheritance of specific traits, and in addition to selection, techniques like hybridization, mutation, and molecular breeding should be used to develop aonla cultivars tailored to industrial needs. Increased research on high-density planting, value addition, and marketing strategies is essential to boost aonla cultivation and facilitate the efficient disposal of produce.

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IMPACT OF INTEGRATED NUTRIENT MANAGEMENT ON PERFORMANCE OF BARLEY (*HORDEUM VULGARE* L.)

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Abstract

The current study was conducted during the Rabi season of 2023-2024 at the experimental field i.e. Kotra Santaur and laboratories of Uttaranchal University Department of Agriculture in Dehradun (Uttarakhand). The research was laid out on Randomized Block Design with three Replication to test seven treatments: T₁ (Control), T₂ RDF (60:40:20), T₃ RDF (100%) + Vermicompost (15t/ha), T₄ RDF (100%) + FYM (10t/ha) + Vermicompost (15t/ha), T₅ RDF (100%) + Poultry Manure (2t/ha), T₆ RDF (100%) + FYM (10t/ha), and T₇ FYM (10t/ha). Growth characteristics and yield components were statistically analyzed. Data on growth characteristics and yield components were gathered and examined statistically. Overall results depicted that among nutrient management practices treatments T₄ recorded significantly higher growth and yield attributing characters: Plant height, Dry matter accumulation, LAI, Days of emergence, grain, straw, and biological yield (kg ha⁻¹), of barley except Plant population, No. of tillers, spike length, and No. of grain per spike was recorded higher in treatment T₃. The fertility of soil also improved after the harvest with the use of inorganic and organic fertilizer mixtures. Performance in terms of yield of barley in treatment T₆ (RDF 100% + FYM 10 t/ha) was at par with treatment T₃ (RDF 100% + Vermicompost 15t /ha) and T₄ (RDF 100% + FYM 10t/ha + Vermicompost 15 t/ha). And, various combinations of RDF, FYM, and vermicompost failed to produce any significant variation in the test weight of barley.

Keywords: Integrated Nutrient Management, Barley, RBD, Growth, Yield.

Introduction

Barley, classified within the grass family Poaceae (Zhou, 2009), stands as an ancient cereal grain, having undergone a transformative journey from primarily serving as a staple grain food to becoming a pivotal malting and feed grain upon domestication (Baik *et.al.*, 2008). This grain holds a significant position as one of the world's most valuable cereal crops, trailing only behind wheat, maize, and rice concerning global production (Lapitan *et.al.*, 2009). With its diploid genome and a low chromosome count of 2n = 14, barley boasts an expansive genome size, encompassing approximately 39,000 genes within

the haploid genome. Despite this complexity, the extensive availability of genomic resources includes a top-tier barley reference genome sequence (Mascher *et.al.*, 2017).

Barley grows in drought-prone and alkaline soils, its straw serving as fodder and brewing malt. With 12.5% moisture, 11.5% albuminoids, 74.0% carbohydrates, 1.3% fat, 3.9% crude fiber, and 1.5% ash, barley differs from wheat. Leading producers like Russia, China, Germany, the US, Canada, Turkey, India, and Australia cultivate barley, with Indian states like Rajasthan, U.P, M.P, Haryana, Punjab, West Bengal, and Bihar prominent. Climatic variability, poor fertilization,

soil conditions, and nutrient imbalances affect yield in dry areas (Karol *et.al.*, 2023). Barley grain aids digestion with its covering and cooling properties. It is also a key industrial raw material for the brewing, whiskey, and beer industries (IIWBR, 2019). Mostly, harvested barley is used in various forms such as flour for “Chapatis” and “Sattu.” It is essential for malt production in beer, whiskey, industrial alcohol, and vinegar. Barley malt syrup is used in candies, breakfast items, beverages, and medicinal preparations. Byproducts from brewing and distilling serve as valuable cattle feed. Bold, plump barley seeds are preferred for pearl barley and powdered products for convalescent diets. Barley is efficient in water usage, tolerant to salinity and alkalinity, and highly resilient to drought.

Using Farmyard Manure (FYM) enhances soil fertility and water-holding capacity (Singh, 2017). All plants need nutrients to thrive, and when a crop is harvested, a large amount of nutrients are extracted and exported. Nutrients are therefore crucial for agricultural production. Then, to produce crops sustainably, the nutrients that are taken out must be supplied with Organic fertilizers, chemical fertilizers, Urban solid waste, or in certain situations, the surrounding environment (Manitoba, 2013). The increased use of synthetic fertilizers has boosted agricultural production but caused micronutrient deficiencies and environmental contamination. This highlights the importance of incorporating organic manures. However, solely relying on organic farming is impractical due to manure scarcity and the impracticality of green manuring in intensive agriculture. Thus, integrated nutrient management is a promising approach for maintaining agricultural stability and productivity (Choudhary *et.al.*, 2018).

Used extensively for food, fodder, and malting, barley is a highly versatile crop. Its adaptability makes it especially suitable for cultivation in varying climate conditions (Sendhil *et.al.*, 2017). Barley-based foods enhance dietary choices with their whole grains, low-fat content, and high fibre. They are ideal for wholesome nutrition and offer various health benefits. The soluble fibre beta-glucan in barley helps lower cholesterol similarly to oats. Additionally, barley products can

reduce postprandial blood glucose and insulin levels (Yadav, 2001). It offers a nutrient-rich profile with 8-10% protein, essential minerals, and B-complex vitamins. While 90% of India's barley is consumed by humans, the US and Europe primarily use it as livestock feed. Barley grains and straw serve as nutritious cattle feed, prized for minimal input needs and adaptability to harsh conditions (Anonymous, 2016). Further, data from the Directorate of Agriculture (DAC) shows that barley cultivation in India covered around 0.67 million hectares, producing approximately 1.61 million tonnes. It is mainly grown in the northern plains, particularly in Uttar Pradesh, Haryana, and Rajasthan. Barley occupied 618.4 thousand hectares, yielding 1590 thousand tonnes, with an average productivity of 25.73 q/ha. Rajasthan is the largest contributor, covering 46% of the cultivable area and producing more than 52% of the total, with 288.2 thousand hectares yielding 831.2 thousand tonnes at an average productivity of 28.84 (IIWBR, 2019). And in Dehradun distt. of Uttarakhand covers an area of 966 ha, 2234 t of production, and 2.31 t/ha yield is obtained in the year 2022-2023 (DEC, 2023).

Material and Method

The experiment was conducted at Kotra Santaur, Uttaranchal University Dehradun (Uttarakhand) during the rabi season of 2023-2024. Dehradun is located at 30° 44' north latitude and 78° 04' east longitude an altitude of 450m above mean – sea level. The experiment was conducted in a Randomized Block Design having three replications with seven treatments viz., Control (T₁), RDF (60:40:20) (T₂), RDF (100%) + Vermicompost (15t/ha) (T₃), RDF (100%) + FYM (10t/ha) + Vermicompost (15t/ha) (T₄), RDF (100%) + Poultry Manure (2t/ha) (T₅), RDF (100%) + FYM (10t/ha) (T₆), and FYM (10t/ha) (T₇). The treatments were allocated to different plots at random in all replications using the random table. For this experiment observations were recorded on growth parameters viz., Plant height (cm), Dry matter accumulation (g/m²), Plant population (m⁻²), Leaf area index (LAI), No. of tillers (m⁻¹), Days of emergence, Days of maturity; yield attributes i.e. No. of grains per spike, Spike length (cm), Test weight (gm), Biological yield (kg ha⁻¹),

Straw and grain yield (kg ha^{-1}), Harvest index (%), and economic studies. Throughout the crop growth period, five plants were randomly selected and labeled in each plot for all growth and development investigations, except dry matter accumulation and leaf area index, which used plants from boundary rows for data collection. The parameters of growth were measured for the first time thirty days after seeding, and then again, every thirty days after that. Each net plot size was 3m x 2m. And, Barley variety – 2035 was used for test crop.

Results And Discussion

Impact on growth parameters

The statistically calculated data of various growth parameters was noted to be a significant increase at all stages in all planting geometries i.e. various days of sowing. In a comparison of all seven treatments, the maximum significant increase was observed while using RDF 100% + FYM 10t/ha + Vermicompost 15t/ha, and the minimum was in Control. For growth parameters i.e. plant height, DMA, LAI, plant population, no. of tillers, days of emergence, and days of maturity was maximum using RDF 100% + FYM 10t/ha + Vermicompost 15t/ha than RDF 100% + Vermicompost 15t/ha except various yield attributes.

Plant Height

Tall T_4 planters using RDF (100%) + FYM (10t/ha) + Vermicompost (15t/ha) significantly increased in plant height at all stages across all planting geometries: at 30 DAS (24.80 cm), (63.20 cm) at 60 DAS, (88.12 cm) at 90 DAS, and (90.26 cm) at 120 DAS. The use of FYM, vermicompost, poultry manure, and RDF produced similar growth results at all stages, while T_1 (Control) had the shortest plant height. The combined application of organic (FYM and vermicompost) and inorganic fertilizers in T_4 led to considerable plant height growth, likely due to the higher nutrient content and growth-promoting compounds in vermicompost and farmyard manure (Table 1).

Table 1: Mean Plant Height (cm) as affected by INM at different phases of growth.

Symbol	Plant Height (cm)			
	30 DAS	60 DAS	90 DAS	Harvest
T1	18.26	49.26	72.06	76.14
T2	21.38	56.08	82.23	85.20
T3	24.45	62.30	87.17	89.34
T4	24.80	63.20	88.12	90.26
T5	22.40	57.53	83.69	87.06
T6	22.69	59.46	84.50	88.24
T7	19.72	53.14	79.16	82.03
SE (m)	0.094	0.57	0.58	0.31
SD (d)	0.13	0.81	0.83	0.45
CD at 5%	0.29	1.80	1.83	0.99

Dry Matter Accumulation

The impact of the combination of organic (Poultry manure, FYM, and Vermicompost) and inorganic in dry matter accumulation was found significant at different- different intervals of sowing. Dry matter accumulation was found maximum using the combination of RDF + FYM + Vermicompost (T_4) as par with the combinations of RDF and Vermicompost (T_6), RDF + FYM, and RDF + Poultry manure (T_5). The minimum was found in the control at different – different stages of DAS. This may be due to the combination of RDF with both FYM and Vermicompost in a suitable quantity, and the interaction of various growth parameters, and vegetative component output. (Table 2).

Table 2: Mean Dry matter Accumulation/meter row length (g/m^2) as affected by INM at Various stages of growth.

Symbol	DMA/meter row length (g/m^2)		
	30 DAS	60 DAS	90 DAS
T1	1.83	14.71	26.5
T2	2.44	17.6	31.3
T3	2.8	18.3	32.8
T4	3.4	18.73	34.1
T5	2.45	17.8	31.5
T6	2.5	17.9	31.82
T7	2.33	16.4	30.2
SE (m)	0.07	0.01	0.08
SE (d)	0.10	0.014	0.11
CD at 5%	0.22	0.032	0.25

Leaf Area Index

LAI was noted to be significantly increased during the use of treatment T_4 [RDF(100%) + FYM(10t/ha) + Vermicompost (15t/ha)]. This might be explained by increased photosynthetic

activity, increased light absorption rate, and improved soil nitrogen uptake (Table 3).

Plant Population

When the plants receive a suitable amount of nutrients during the growing season, the plant population is affected. The high plant population was observed in treatment having RDF (100%) + Vermicompost (15t/ha) i.e. in T₃ (Table 4). The minimum plant population was seen in the T₁ (Control) except for T₇ i.e. FYM (10t/ha).

No. of Tillers

Data about the no. of tiller at 60 DAS was included in Table 4 and a graphical representation for it. Data analysis reveals that no. of tillers significantly increases with the various applications of treatments, with T₃ showing the maximum no. of total tiller at 60 days after sowing i.e. (110.46). The minimum no. of total tiller was recorded in T₁.

Days of Emergence and Maturity

The days it took for barley to emerge and tiller under varied conditions of RDF, FYM, and vermicompost were significantly different from one another. This lack of variance is probably because nitrogen levels are relevant for seedling emergence. After all, during emergence, seedlings obtain nutrients from their storage organs. Furthermore, this might be explained by the genetic makeup of barley itself, since some growth and development factors significantly affected the genotypic property known as phenology. Also, minimum number of days of emergence and maturity were all noted in treatment T₁ (Control). While treatment T₇ (RDF + FYM 10t/ha + Vermicompost 15 t/ha) took the same amount of days to mature as treatment T₅, treatment T₆, and treatment T₃ took much longer. When combined fertilizers are applied more frequently, the plant's photosynthetic efficiency increases, delaying the crop's maturity in the process. T₄ took the maximum day for emergence and maturity i.e. (7.43) and (121.73.)

Table 3: Mean LAI as affected by INM at Various phases of growth.

Symbol	LAI		
	30 days	60 days	90 days
T1	0.41	1.10	1.55

T2	0.63	1.43	2.02
T3	0.95	1.78	2.55
T4	1.02	1.88	2.67
T5	0.65	1.57	2.17
T6	0.86	1.66	2.41
T7	0.48	1.25	1.78
SE (m)	0.03	0.015	0.018
SE (d)	0.04	0.021	0.026
CD at 5%	0.09	0.046	0.057

Table 4: Mean Plant Population, No. of Tillers, Days of Emergence, and Days of Maturity.

Symbol	Plant Population at 20 DAS / Meter row Length	Number of Tillers	Days of Emergence	Days of Maturity
T1	31.27	87.03	6.40	118.76
T2	31.73	98.36	6.98	119.46
T3	32.60	110.46	7.39	121.01
T4	32.42	108.36	7.43	121.73
T5	31.79	100.20	7.13	120.10
T6	32.04	105.51	7.30	120.45
T7	31.42	92.03	6.96	119.9
SE (m)	0.19	0.481	0.091	0.082
SE (d)	0.27	0.683	0.12	0.11
CD at 5%	0.61	1.51	0.27	0.25

Yield Attributes

The perusal of statistically calculated data revealed that no. of grains per spike (38.26), spike length (6.74 cm), and were highest in treatment T₃ but statistically at par with treatments T₆ and T₄ except test weight (39.87g) in T₄. The lower values were noted in treatments T₇ and T₁ this is because the amount of photosynthesis that transferred from the source to the sink was reduced because the plants had to use the minimal quantity of nitrogen that was available.

The yields were recorded as significantly greater in T₄ [RDF(100%) + FYM(10t/ha) + Vermicompost (15t/ha)] as compared to other treatments due to adequate nitrogen availability, enhanced by vermicompost, which led to increased dry matter accumulation, better vegetative growth, and higher grain yield due to the presence of macro and micronutrients and growth promoters. In contrast, treatments with reduced nutrient supply showed the lowest yield due to poor growth and yield attributes.

In terms of straw yield the maximum yield was recorded in treatment T₄ which is at par with T₃

which may be because of the higher density of tillers and increased dry matter production per unit area, resulting from efficient nutrient assimilation and absorption, led to better vegetative growth. The harvest index was not much affected by the different treatments used except by T₁ i.e. Control but T₄ (47.97%) gave the maximum harvest index value.

Table 5: Mean No. of Grains per Spike, Spike Length, and Test Weight.

Symbol	No. of grains per spike	Spike Length (cm)	Test weight (g)
T1	26.67	5.63	38.21
T2	30.15	6.08	38.78
T3	38.26	6.74	39.04
T4	37.47	6.51	39.87
T5	31.67	6.18	38.13
T6	34.70	6.32	38.95
T7	29.01	5.86	38.83
SE (m)	0.013	0.012	0.35
SE (d)	0.018	0.017	0.49
CD at 5%	0.039	0.037	NS

Table 6: Mean Grain Yield, Straw Yield, and Harvest Index (%).

Symbol	Grain Yield (Kg ha ⁻¹)	Straw Yield (Kg ha ⁻¹)	Biological Yield (Kg ha ⁻¹)	Harvest Index (%)
T1	1945	2489	4434	43.86
T2	2667	2924	5607	47.55
T3	3053	3480	6533	46.72
T4	3253	3526	6781	47.97
T5	2793	3292	6083	45.91
T6	2962	3324	6286	47.11
T7	2339	2802	5142	45.49
SE (m)	0.49	0.69	1.14	0.06
SE (d)	0.682	0.97	1.60	0.08
CD at 5%	1.507	2.15	3.54	0.18

Conclusion

Performance in terms of growth and yield of barley in T₆ (RDF 100% + FYM 10t/ha) was at par with T₃ (RDF 100% + Vermicompost 15t/ha) and T₄ (RDF 100% + FYM 10t/ha + Vermicompost 15t/ha). Hence the combination of inorganic with organic with a suitable quantity increases the growth of plants and helps to boost the soil's ability to retain water, improving soil aeration and fertility.

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Authors

DK & RS carried out the research work and data collection. JB, MN, and AK participated in the writing, arrangement of the manuscript, and references. All authors approved the manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that there is no conflict of interest regarding the conduct and writing of this manuscript.

Ethical issues: None

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ESSENTIAL NUTRIENTS OF MAJOR VEGETABLES & THEIR HEALTH IMPACTS

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Abstract

Vegetables are integral to a healthy diet due to their exceptional nutritional quality and numerous health benefits. They are a rich source of essential nutrients, including vitamins, minerals, and dietary fibre, which are vital for maintaining overall health and preventing chronic diseases. Vegetables provide low-calorie, nutrient-dense options that support cardiovascular health, enhance digestive function, and bolster immune defences. Additionally, they are abundant in phytochemicals such as antioxidants and anti-inflammatory compounds, which contribute to their role in disease prevention and health promotion. This abstract highlights the importance of incorporating a diverse array of vegetables into daily nutrition to leverage their health benefits, underscoring their role in fostering long-term well-being and improving quality of life.

Keywords: Vegetables, Nutrients, Health benefits

Introduction

Vegetables, defined as those herbaceous plants of which some portion is eaten, either cooked or raw, during the principal part of the meal, constitute an important segment of our agricultural system. Starchy vegetables like potato, sweet potato, cassava and yam are rich sources of carbohydrates. Legume vegetables like peas and beans are rich in proteins. Besides, vegetable in general are good sources of vitamins, minerals and fibres. (Ram HH, 2022). Some phytochemicals of vegetables are strong antioxidants and are thought to reduce the risk of chronic disease by protecting against free-radical damage, by modifying metabolic activation and detoxification of carcinogens, or even influencing processes that alter the course of tumour cells (Albushita *et al.* 2000). A strong association exists between our daily diet and balanced health, which includes reduced risk of cancer, good vision, gastrointestinal health cardiovascular diseases, ulcer, anaemia, diabetes, high or low blood pressure and arthritis (Prior and Cao 2000; Keatinge *et al.*, 2010). Globally, due to

consumption of unbalanced diets and poor intake of vegetables, 31% of cardio-vascular disease and 11% of heart stroke has been estimated. It has been estimated as per World Health Report, 2007, responsible causing approximately 2.7 million deaths annually, due to improper habit of consuming indigestible dietary fibre and carbohydrates it contributes to mortality (Dias, 2011). The promotion of healthy vegetable products has coincided with a surging consumer interested in the healthy functionality of food. There is an increasing awareness among the general public of the advantages of diets rich in vegetables to ensure an adequate intake of most vitamins and micronutrients, dietary fibres, and phytochemicals that promote health. Consumers interest in whole foods with enhanced nutritional qualities is at an all-time high, and more consumers are choosing foods on the basis of their health benefits. This article makes a review and discusses the nutritional quality and health benefits of the major groups of vegetables.

Nutritive value and health benefits of vegetables

There is a general belief among nutritionists and health professionals that the health benefit of vegetables should not be linked to only one compound or one type of vegetable, but rather a balanced diet that includes more than one type of vegetable is likely to provide better protection. All the vegetables may offer protection to humans against chronic diseases. With the exception of glucosinolates and thiosulfides, which are unique to the crucifers and alliums, the phytonutrient content of a number of other vegetables consist primarily of vitamin C, fibre, selenium, folate and polyphenolics (carotenoids and flavonoids). In this section we will highlight the health benefits of the most studied and consumed vegetables namely crucifer, allium and solanaceous vegetables.

Solanaceous Vegetables

The use of solanaceous vegetables in traditional medicine is ancient. There are significant differences in the phytonutrient content between solanaceous vegetables, and therefore each vegetable will be examined separately.

Tomato

The tomato has a unique nutritional and phytochemical chemical profile. The major phytochemicals in tomato are the carotenoids consisting of 60% to 64% lycopene, 10% to 12% phytoene, 7% to 9% neurosporene, and 10% to 15% carotenes (Clinton *et al.* 1998). Based on a fresh weight basis, tomato (on average) contains about 35 mg/kg of lycopene, with red cultivars containing in average 90 mg/kg of lycopene and yellow ones only 5 mg/kg (Scott and Hart 1995). Processed tomatoes (sauce, paste, juice, and ketchup) contain 2- to 40-fold higher lycopene than fresh tomatoes (Clinton *et al.* 1998; Tonucci *et al.* 1995; Gerster *et al.* 1997). Tomato fruits are also an excellent source of ascorbic acid, about 200 mg/kg and are the major source of vitamin C next to citrus (Rao *et al.* 2007). Tomato contains small but significant amounts (1 - 2 mg/kg) of lutein, α -, β -, and γ -tocopherols, and conjugated flavonoids (Albushita *et al.* 2000; Leonardi *et al.* 2000; Albushita *et al.* 1997). In a study of 20 tomato cultivars, total flavonoids content ranged from 1.3 to 22.2 mg/kg with about 98% present in the skin

(Stewart *et al.* 2000). Flavonoids in fresh tomato are present only in the conjugated form as quercetin and kaempferol (Crozier *et al.* 1997), but processed tomato products contain significant amounts of free flavonoids (Stewart *et al.* 2000).

Flavonoids content is affected by cultivar and culture. For example, cherry tomatoes have a marked the higher flavonoids content than standard or beef tomato cultivars and field-grown fruits have higher flavonoids content than greenhouse grown (Simon *et al.* 2007; Stewart *et al.* 2000). Studies reported that when tomatoes and tomato products are removed from daily consumption, the antioxidant capacity of plasma decreases and when they are added back it increases (Hadley *et al.*, 2003). A daily consumption of tomato products for 2-4 weeks enhances the defence mechanism by antioxidant enzyme and reduces plasma lipid peroxides activity (Briviba *et al.*, 2004; Upritchard *et al.*, 2000; Bub *et al.*, 2005). Reports suggested that a daily intake of tomato for more than 8 weeks reduced the ultraviolet light-induced erythema as 40 gm tomato contains approximately 16 mg of lycopene (Stahl *et al.*, 2001; Stahl *et al.*, 2006; Stahl and Sies, 2002). About 178 research papers (original) reported that the relationship between humans and lycopene which includes tomato (both raw and processed) and cancer risk (Burton-Freeman and Reimers, 2011). Among all these investigations, cancer related to tomato intake, lycopene consumption and prostate cancer is the most widely studied. Minimised risk of prostate cancer upto 35% was observed, when there is consumption of 10 or more servings of tomato products per week and it was also found effective against more aggressive and advanced stages of cancer (Giovannucci *et al.*, 1995).

Brinjal (Eggplant):

It is the most widely adapted vegetable crop grown throughout the tropics, subtropics and Mediterranean region. One-hundred-gram edible portion of brinjal fruit contains 92.7% moisture, 24.0% calories, 4.0% carbohydrates, 1.4 g protein, 0.3 g fats, 1.3 g fibers, 124.0 (I.U.) Vitamin A and 12.0 mg Vitamin C (Chen and Li, 1996). It also contains 52.0 mg Chlorine, 47.0 mg Phosphorus, 44.0 mg Sulphur and other Minerals (Aykroyd, 1963). In Ayurveda, an Indian system of medicine,

white fruited types are recommended for diabetic patients, and roots for the treatment of asthma. In addition to featuring a host of vitamins and minerals, eggplant also contains important phytochemicals which have antioxidant activity. Phytochemicals contained in eggplant include phenolic compounds, such as caffeic and chlorogenic acid, and flavonoids, such as nasunin.

Nasunin or delphinidin-3-(coumaroylrutinoside)-5-glucoside is the major phytochemical in eggplant. Nasunin is part of the anthocyanin purple pigment found in the peel of eggplant, purple radish, red turnip, and red cabbage (223-225). It is considered to be a very good source of nicotine having a concentration of 0.01mg/100g, as compared to other vegetables. However, the presence of nicotine is negligible compared to passive smoking (Domino *et al.*, 1993).

Chilli and Capsicum:

It is also known as Hot and Sweet peppers. A wide variability is present in the colours, shape and size of peppers. It is very well accepted for adding flavours, crunch and pungency to a number of dishes. It is an excellent source of Vitamin C, K, carotenoids and flavonoids when consumed fresh (Bosland, 1996). It is very effective against cell damage, diseases related to old age and strengthen immune system, due to presence of antioxidant, Vitamin A and C. Its adequate consumption helps in reducing inflammation; presence of Vitamin K protects cells from oxidative damage, strengthens bones and promotes blood clotting. It is also effective against cancer due to presence of lycopene especially in red peppers. It is not only high in phytochemicals, but also contains a good proportion of fibre. Capsaicin acts as a major constituent in pharmaceutical formulation for the treatment of pain, ache, burn and rheumatoid arthritis. It also possesses analgesic, antibacterial and antidiabetic properties. It is found to be beneficial for bladder hypersensitivity, vasomotor rhinitis and hyperreflexia of spinal origin (Szallasi and Blumberg, 1999). Fresh chilli of 100 gm contains 240% of vitamin C, 32% of vitamin A, 39% of vitamin B6, 14% of copper, 13% of iron and 7% of potassium (Frei and Lawson, 2008).

Potato

It is considered to be the third most important

staple food after rice and wheat. On per-day basis, potato yields more energy as compared to cassava and cereals. It isn't only an important source of carbohydrates but also amino acids. The carbohydrates are available in the form of starch, which is slightly difficult on the part of our small intestine to digest and so it reaches the large intestine intact. The resistant starch is considered as the dietary fiber which is associated with a member of health benefits like protection against cancer, increase in insulin sensitivity, lowers cholesterol and triglyceride levels and even reduces fat storage (Raben *et al.*, 1994; Hylla *et al.*, 1998). The residual starch content (resistant) depends upon the method of preparation as cooked potato contains 7% resistant starch, which further increases to 13% upon cooling (Englyst *et al.*, 1992). A daily consumption of more than RDA of carbohydrates makes the individual obese. Although potato contains a less amount of protein (less than 6%), but it is considered as the best among other vegetables having protein and even comparable to cow's milk. It is because the protein content in potato is of very high quality as it is rich in amino acid, lysine and other metabolites (McCay *et al.*, 1987; Okeyo and Kushad, 1995; Friedman, 1996).

Cruciferous Vegetable

Cruciferous vegetables (*Brassicaceae* or *Cruciferae* family) which include, cabbage, broccoli, cauliflower, Brussels sprouts, kales, kailan, Chinese cabbage, turnip, rutabaga, radish, horseradish, rocket, watercress, mustards, among other vegetables, provide the richest sources of glucosinolates in the human diet. Epidemiological studies have suggested that diets rich in broccoli, may reduce the risk of prostate cancer, and consumption of one or more portions of broccoli per week can reduce the incidence and the progression from localized to aggressive forms of prostate cancer (Kirsh *et al* 2007; Traka, 2010). Crucifers also contain significant amounts of dietary fiber. Dietary fiber content of cauliflower was estimated to be about 5% of the total fresh weight or about 50% of the total dry weight, consisting of about 40% nonstarch polysaccharides (Fermentia *et al.* 1999). Cellulose and lignin concentrations in Brussels sprouts were estimated to be 36% and 14.5%, while in cauliflower they were estimated to

be about 16% and 13% of the total dry matter, respectively (Rahn et al. 1999). Other antioxidants in crucifers include flavonoids. (Miean and Mohamed. 2001) examined the flavonoid content of 62 vegetables and found that broccoli, cauliflower, cabbage, Chinese cabbage, and kailan contained between 148 and 219 mg/kg of flavonoids. Broccoli contained myricetin, quercetin, and luteolin; cauliflower contained myricetin and quercetin; kailan contained quercetin and apigenin; while cabbage contained only myricetin.

Alliums

Alliums vegetables (*Alliaceae* family) include, garlic, onion, leek, chive, Welsh onion, among other vegetables. They are rich in a wide variety of thiosulfides, which have been linked to reducing various chronic diseases. Similar to glucosinolates in crucifers, the types and amounts of thiosulfides in alliums vary significantly. Typically, they contain 1% to 5% nonprotein sulphur compounds, on a dry weight basis. Kubec *et al.* 1999) reported significantly variability in the total thiosulfide (0.02% to 1.3% fresh weight) content and in the relative proportion of these compounds between and within alliums, even when grown under identical conditions. They found that the total thiosulfide contents in green onion leaves, chive, and onion bulb were 0.2, 0.72, and 1.02g/kg fresh weight, respectively. The type of thiosulphides in these vegetables were also variable. For example, onion bulbs contained 34% methane, 5% ethine, 6% propiin, 5% alliin, and 49% isoalliin (Kubec et al 2000), while garlic cloves contained about 92% alliin, 8% methiin, and trace amounts of ethiin, propiin, and isoalliin (Kubec et al. 1999). Prevention of cardiovascular diseases has been attributed to regular garlic consumption. Onions also contain a number of bioactive molecules that can presumably reduce the risks for cardiovascular diseases (Osmont et al 2003). A preliminary study conducted in humans showed that the consumption of the equivalent of three onions in a soup was sufficient to significantly reduce the blood platelet aggregation.

Conclusions

The nutritional quality and health benefits of vegetables are both profound and multifaceted.

Vegetables are rich in essential vitamins, minerals, and dietary fiber, which play crucial roles in maintaining overall health and preventing chronic diseases. Their low calorie and high nutrient density make them a cornerstone of a balanced diet, supporting cardiovascular health, aiding in digestion, and enhancing immune function. Additionally, the variety of phytochemicals found in vegetables, such as antioxidants and anti-inflammatory compounds, further contribute to their protective effects against various ailments. Incorporating a diverse array of vegetables into daily meals not only promotes optimal health but also enriches the diet with a wide range of flavours and textures. Embracing vegetables as a key component of a healthy lifestyle can lead to long-term wellness and improve quality of life. The availability of a large diversity of vegetables year-round, allied to increase in mean per capita incomes in recent years and knowledge of vegetable health benefits, have enable consumers to include a variety of health promoting phytonutriceuticals in their diet.

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PHYSIOLOGICAL, BIOCHEMICAL, AND MOLECULAR BASIS OF PLANT RESPONSES TO DROUGHT STRESS

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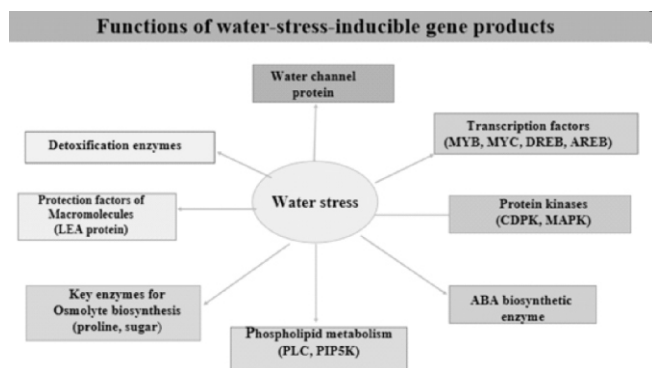
Abstract

The survival of plants in arid environments relies on their intricate responses to drought stress, encompassing physiological, biochemical, and molecular mechanisms. In the face of limited water availability, plants exhibit remarkable adaptations to minimize water loss and sustain vital functions. Physiologically, stomatal closure reduces transpirational water loss, while growth reduction and wilting help conserve water. Root growth alterations enable exploration of deeper soil layers for water acquisition. Biochemically, osmotic adjustment through accumulation of compatible solutes maintains cellular turgor pressure. Antioxidant production counteracts reactive oxygen species (ROS) induced by water stress. Notably, abscisic acid (ABA) accumulates, orchestrating stress responses including stomatal closure and gene regulation. Molecularly, gene expression changes underlie the activation of stress-responsive genes. Transcription factors like DREB and bZIP modulate gene expression, while ABA-dependent and ABA-independent pathways govern signaling. LEA proteins and chaperones shield cellular structures, and microRNAs fine-tune post-transcriptional regulation. This comprehensive framework underscores the remarkable capacity of plants to adapt to drought stress through an integrated network of physiological, biochemical, and molecular strategies. Understanding these responses holds promise for enhancing crop resilience and agricultural sustainability in water-scarce environments.

Introduction

Drought stress is the significant environmental factor that affects the growth of plant and productivity worldwide. Plants have evolved complex mechanisms to cope with water scarcity, enabling them to survive and thrive in arid conditions. These mechanisms involve a combination of physiological, biochemical, and molecular responses that help plants survive in drought stress and mitigate the effects of drought stress. We will delve the intricate processes that underlie these responses and explore how they contribute to a plant's ability to withstand drought. Security of food has become a significant global concern due to population expansion and climate change. By 2050, it will be anticipated that the

growing demand will necessitate a two fold increase in food production. Understanding the physiological and genetic improvement of crop responses to drought is essential for accelerating the development of drought tolerance in breeding. However, the ability to tolerate drought is a complicated polygenic characteristic that is influenced due to the environment and several genetic loci. Thus, the evaluation standards for agricultural drought tolerance were examined in the current review, which was then followed by ways for mining drought tolerance genes and strategies for enhancing crop drought tolerance



1. Physiological Responses to Drought Stress:

Plant which responses to drought stress are very complex and involve various physiological mechanisms that help plants survive and adapt to water scarcity. These responses are crucial for the survival and productivity of plants in arid and drought-prone environments. Following are a few of the most important physiological reactions of plants to drought stress.:

Stomatal Closure: The primary responses to stress due to drought is the closure of stomata, tiny openings on the surface of leaves and stems. This lessens the input of CO₂ for photosynthesis as well as water loss through transpiration. Stomatal closure helps conserve water but can also reduce carbon assimilation and growth.

Root Growth: Drought stress often leads to alterations in root growth and architecture. Plants may develop deeper roots to access water stored deeper in the soil or modify their root system to explore larger soil volumes. These adaptations help plants access water resources more efficiently.

Osmotic Adjustment: To maintain cell turgor pressure and prevent wilting, plants can accumulate solutes such as sugars and ions in their cells. This osmotic adjustment helps maintain cell water potential and prevents water loss from plant cells.

Leaf Rolling and Curling: Some plants exhibit leaf rolling or curling as a response to drought stress. This reduces the leaf surface area exposed to the air, minimizing water loss through transpiration.

Photosynthetic Modifications: Due to low CO₂ uptake and stomatal closure caused by

drought stress, photosynthesis is frequently reduced. However, certain plants may use systems like C₄ or CAM photosynthesis to increase carbon fixation when there is a water shortage. Qualities in connection with photosynthesis Drought has an effect on photosynthesis by lowering stomatal aperture, enzyme concentrations, and activities. It also drastically affects CO₂ uptake. A high throughput measure to detect photoinhibition brought on by a water shortage is chlorophyll fluorescence. Fluorescence measurements used to identify changes in CO₂ assimilation, linear electron transport, and photosystem II photochemistry during drought stress. Fluorescence imaging can be used to examine a large number of plants for photosynthetic disruption during drought circumstances. Crops with higher levels of chlorophyll make better use of light.

Accumulation of Protective Compounds To lessen the negative consequences of drought-induced oxidative stress, plants may generate osmoprotectants like proline and soluble carbohydrates as well as antioxidants like superoxide dismutase and catalase.

Abscisic Acid (ABA) Signaling: ABA is a key phytohormone involved in regulating plant responses to drought stress. It triggers various physiological responses, including stomatal closure, to reduce water loss.

Cellular Repair Mechanisms: Drought stress can lead to cellular damage, particularly in membranes and proteins. Plants activate repair mechanisms to mitigate damage and maintain cellular integrity.

Senescence: Under prolonged or severe drought stress, plants may undergo premature senescence, shedding older leaves to allocate resources to more critical tissues. This helps ensure the survival of essential plant parts.

Hydraulic Redistribution: Few plant species can move water from deeper soil layers to shallower ones through root systems, benefiting both the plant and neighboring plants. This redistribution can help alleviate drought stress.

These physiological responses to drought are not exclusive and vary among plant species and their degree of adaptation to arid environments. Understanding these responses is essential for

developing strategies for drought tolerance in crops and mitigate the negative effects of stress on plant ecosystems and agriculture.

2. Biochemical Responses to Drought Stress:

Explore the biochemical changes that occur in plants in response to drought stress, such as the production of osmoprotectants (e.g., proline, sugars), antioxidants, and the accumulation of compatible solutes.

Drought stress is a significant environmental challenge for plants, and they have developed various biochemical mechanisms to cope with this stress. These mechanisms involve changes in gene expression, the synthesis of specific molecules, and alterations in metabolic pathways. Here, I'll outline some of the key biochemical responses of plants to drought stress:

Osmotic Adjustment: When water availability decreases, plants undergo osmotic adjustments to maintain cell turgor pressure. This involves the accumulation of compatible solutes such as proline, sugars (e.g., sucrose and trehalose), and amino acids (e.g., glycine betaine). These solutes help in maintaining cellular water potential and stabilize cell membranes.

Antioxidant Defense: Drought stress often leads to the generation of reactive oxygen species (ROS) such as superoxide radicals and hydrogen peroxide. To counteract the damaging effects of ROS, plants increase the production of antioxidants like superoxide dismutase, catalase, peroxidases, and ascorbate.

ABA Signaling: Absciscic acid (ABA) is a phytohormone that plays a central role in plant responses to drought stress. It helps in stomatal closure to reduce water loss through transpiration. ABA biosynthesis increases in response to drought, and it acts as a signaling molecule to trigger various adaptive responses.

Stomatal Regulation: Drought stress triggers the closure of stomata, small openings in the leaf epidermis that regulate gas exchange and water loss. This closure reduces water loss through transpiration and helps conserve water within the plant. ABA and other signaling molecules are involved in this process.

Cell Membrane Stability: Drought stress can lead to membrane damage due to lipid

peroxidation. To maintain cell membrane stability, plants produce lipid molecules with more unsaturated fatty acids, which are less susceptible to peroxidation. This adjustment helps preserve cell integrity.

Hormonal Responses: Besides ABA, other hormones like ethylene, jasmonic acid, and salicylic acid also play roles in plant drought responses. They can regulate various processes such as root growth, leaf senescence, and stress-related gene expression.

Gene Expression: Drought-responsive genes are activated to enable the plant to adapt to water scarcity. These genes code for proteins involved in stress tolerance, including enzymes for osmoprotectant synthesis, ion transporters, and stress-related transcription factors.

Metabolic Adjustments: Drought stress often leads to alterations in primary and secondary metabolism. For example, the Krebs cycle may slow down, and glycolysis may become more active to provide energy and carbon skeletons for stress-related processes. Secondary metabolites like flavonoids and phenolics can increase, contributing to antioxidant defense.

Root Modifications: Plants may develop deeper and more extensive root systems to access water stored deeper in the soil. This involves changes in root architecture and the expression of genes related to root growth and development.

Protein Chaperones: Molecular chaperones like heat shock proteins (HSPs) are upregulated in response to drought stress. They assist in the proper folding of proteins, preventing protein denaturation and aggregation under stress conditions.

These biochemical responses collectively help plants adapt to drought stress by maintaining water balance, protecting cellular structures, and activating various defense mechanisms. Understanding these processes is essential for developing drought-tolerant crop varieties and sustainable agricultural practices in regions prone to water scarcity.

Explain how these biochemical responses protect cellular structures and maintain metabolic processes.

3. Molecular Responses to Drought Stress:

Plant responses to drought stress are complex and involve various molecular mechanisms that help plants adapt and survive in water-limited conditions. These responses are critical for plant survival because water is essential for various physiological processes in plants, including photosynthesis, transpiration, and nutrient uptake. Here, I'll provide an overview of the molecular basis of plant responses to drought stress.

Signal Perception and Transduction:

Abscisic Acid (ABA) Signaling: ABA is a key phytohormone that plays a central role in the plant's response to drought stress. When drought conditions are sensed, plants produce and accumulate ABA. ABA acts as a signaling molecule that triggers a cascade of molecular events.

Receptor Proteins: ABA receptors, such as PYR/PYL/RCAR proteins, perceive ABA and initiate a signaling cascade.

Protein Phosphorylation: Protein phosphorylation cascades regulated by kinases, such as SnRK2 (sucrose non-fermenting-1-related protein kinase 2), are a component of ABA signalling and are responsible for a variety of downstream reactions.

Stomatal Closure:

ABA signaling leads to the closure of stomata (small openings on leaves) to reduce water loss through transpiration.

Osmotic Adjustment:

In response to drought, plants accumulate compatible solutes (e.g., proline, sugars) to maintain cellular turgor pressure and osmotic balance.

Antioxidant Defense:

Drought stress can lead to the production of reactive oxygen species (ROS) in plant cells. Plants activate antioxidant enzymes like superoxide dismutase (SOD), catalase (CAT), and peroxidases to scavenge ROS and prevent oxidative damage.

Molecular Chaperones:

Heat shock proteins (HSPs) and molecular chaperones help protect proteins from denaturation and aggregation under drought stress.

Transcriptional Regulation:

Transcription factors (TFs) like DREB (dehydration-responsive element-binding), AREB/ABF (ABA-responsive element-binding factor), and MYB play pivotal roles in regulating the expression of stress-responsive genes.

Gene Expression Changes:

Many genes involved in stress responses are upregulated during drought stress, including those encoding enzymes for osmoprotectant synthesis, detoxification enzymes, and proteins involved in water transport.

Root Modifications:

Plants may alter root morphology and architecture to enhance water uptake, and certain genes and signaling pathways (e.g., auxin-related pathways) are involved in these responses.

Senescence and Dormancy:

In extreme drought conditions, some plants enter a state of dormancy or undergo senescence in order to conserve resources and survive until more favorable conditions return.

Epigenetic Changes:

Epigenetic modifications, such as DNA methylation and histone modifications, can also play a role in regulating gene expression under drought stress.

It's important to note that the specific responses to drought stress can vary among different plant species and even among different genotypes within the same species. Furthermore, the interaction of multiple signaling pathways and the crosstalk between various stress responses make the molecular basis of plant responses to drought stress a complex and dynamic field of study. Researchers continue to explore these mechanisms to develop drought-resistant crop varieties and improve our understanding of plant stress responses.

Genetic and Genomic Approaches in Studying Drought Responses:

Breeders have unintentionally chosen target genes through the history of crop breeding by assessing phenotypic features. Conventional breeding, which has relied for many years on multilocation phenotypic selection, is ineffective.

Utilising molecular breeding technologies will accelerate the breeding process, make genotype selection easier, and increase the effectiveness of creating drought-tolerant cultivars.

Marker-Assisted Selection

Breeders use marker-assisted selection (MAS), a selection method based on QTL or gene markers, to speed up plant breeding programmes. Marker-assisted pedigree selection (MAPS), genomic selection (GS) or genome-wide selection (GWS), marker-assisted recurrent selection (MARS), and marker-assisted backcrossing (MABC) are numerous kinds of MAS that can be categorised based on the objective of the selection. [Gupta *et al.*, 2020] summarised the potential significance of QTLs for the enhancement of drought tolerance using MAS after reviewing the genetics of significant quantitative features in wheat, such as a resistance to abiotic stress. Little progress has been made for MAS despite the existence of a significant number of important QTL for drought tolerance. For instance, in rice, the pyramiding of six large-effect QTL for drought adaptation has increased Asian cultivars' drought tolerance. [Kumar *et al.*, 2014]. Under rainfed conditions, a significant QTL (Qyld.csdh.7AL) was introduced into wheat cultivars using MAS to create a high-yield genotype [Gautam *et al.*, 2021]; under drought conditions, the grain yield was improved by the introduction of QTL on 7AS and 2BS Merchuk *et al.*, 2016]. Additionally, functional molecular indicators of potential drought tolerance genes have been created for use in breeding. [Wang *et al.*, 2021].

Genomic Selection

Genomic Sequencing Crop breeding has used MAS, but because to the restricted number of molecular markers available, its effectiveness is constrained. Most agronomic parameters, including drought, are quantitative features regulated by several minor effect genes. Genomic selection, a potential breeding technique, offers an alternative to conventional MAS by using genome-wide markers to estimate the breeding values of individuals [Guo *et al.*, 2019]. In maize, rice and wheat GS has been demonstrated to increase breeding efficiency and speed, and high prediction accuracy has been attained for the yield and a number of other traits. However, the

genomic selection for enhancing drought tolerance should be studied due to the genetic complexity of its properties.

Genetic Improvement Using

Techniques for Transgene and Genome Editing In addition to identifying the candidate genes, we can apply transgenic technology, such as OE, RNAi, VIGS, ZFN, TALEN, and CRISPR, to increase the crop's resistance to drought [Hanna *et al.*, 2020]. Genetically engineered crops are currently used extensively throughout the world. Herbicide resistance genes (Bar), insect resistance genes (Bt), and disease resistance genes are the genes most frequently utilised in transgenic crops; drought tolerance genes are rarely used. The genetic development of agricultural drought resistance will be aided by transgenic technology and gene editing technologies. For instance, CRISPR technologies can not only enable precise editing, such as base editing, prime editing, and gene targeting, but they can also introduce tiny insertion or deletion changes at the target loci. [Chen *et al.*, 2019]

Genetic Improvement Combined with the Chemical Approach

As a significant hormone, ABA aids in the ability of crops to withstand drought, but because of its chemical instability and quick catabolism, its use in the field is constrained. Numerous studies have been done to find more stable ABA analogues, including those on pyrabactin, AM1 (ABA mimic 1)/quinabactin, cyanabactin, opabactin, and AMFs [Vaidya *et al.*, 2019]. AMFs are additionally applied to PYL2 overexpression transgenic plants, enhancing their drought resistance by combining pharmacological and genetic techniques. Engineering an ABA receptor is another method to increase crop drought tolerance. Transgenic plants with better drought tolerance include ABA receptor PYR1 variants that are sensitive to the agricultural drug mandipropamid. [Park *et al.*, 2015].

Molecular Design Breeding

Enhancing drought tolerance may be accomplished through Molecular Design Breeding, a highly integrated system based on biotechnology and bioinformatics [Lavarenne *et al.*, 2018]. It is capable of designing and modifying genotypes to

satisfy varied breeding goals in various ecological contexts and water conditions. The ideal genotypes can be found during crossover, selection, transgene and genome editing based on the molecular design breeding approach.

Conclusion and Perspectives:

Most transgenic plants possessing traits of drought tolerance were developed using constitutive promoters, such as actin, CaMV35S, and ubiquitin, which were employed to over express particular genes. However, overexpression of a gene often results in the yield penalty due to stress-induced energy consumption. Thus, it should be considered mining drought-tolerant genes that are not subject to production penalties or fine-tuning these genes using appropriate stress-inducible promoters in order to reduce yield penalties. The majority of the genes discussed in this work have been demonstrated to improve drought resistance in growth chambers or greenhouses, but their usefulness has not been extensively tested in the field. This is particularly troublesome for plants that are under water stress because root development in controlled conditions such as pots cannot be compared to how they react to deep soil water profiles, which has a significant effect on their capacity for adaptation and productivity. Therefore, in order to create a proof of concept for the application of these drought-tolerant genes in crop breeding, scientists and breeders still need to work together. Drought stress affects crop plants at different growth and development phases. Physiological, biochemical, and morphological changes can help plants adjust to drought stress, but these genetically controlled reactions are incredibly complicated.

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A REVIEW ON CLIMATE SMART AGRICULTURE (CSA): RECENT ADVANCEMENTS, CHALLENGES, AND FUTURE DIRECTIONS

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Abstract

A Review On Climate Smart Agriculture (Csa): Recent Advancements, Challenges, And Future Directions

CSA integrates various practices, such as efficient water use, improved soil management, and diversified cropping systems, to achieve these goals. It involves collaboration between farmers, governments, and organizations to implement strategies that are both economically viable and environmentally friendly. Global climate change has posed serious threats to agricultural production. Climate-smart agriculture (CSA) is a concept that can provide a solution to the challenges that agricultural development faces. It can do so in a sustainable way by increasing adaptability, decreasing GHG emissions, and ensuring national food security. A review on the recent advancements, challenges, and future directions of CSA will be quite timely and valuable. In this paper, the definition and development goals of CSA are identified. Then, the recent advancements of CSA in developing and in developed countries are reviewed. The existing problems and challenges in CSA are analyzed and pointed out. Finally, the proposals on prospects and directions for CSA in the future are proposed.

Key Practices:

- Organic farming and reduced chemical use.
- Soil conservation and biodiversity enhancement.
- Fair labor practices and community engagement.

Intersection and Synergies:

- **Overlap:** Both CSA and Sustainable Agriculture aim to enhance productivity, maintain environmental health, and support farming communities.
- **Complementary Goals:** CSA's focus on climate adaptation and emission reduction complements the broader environmental and social goals of Sustainable Agriculture.

In essence, CSA can be seen as a subset of

Sustainable Agriculture with a specific emphasis on addressing climate change, while Sustainable Agriculture encompasses a broader range of practices focused on overall environmental, economic, and social sustainability.

Keywords: Climate Change; Climate-Smart Agriculture; Internet Technology; Management Technology; MDG and Food Security.

Introduction

CSA integrates various practices, such as

efficient water use, improved soil management, and diversified cropping systems, to achieve these goals. It involves collaboration between farmers, governments, and organizations to implement strategies that are both economically viable and environmentally friendly. Climate Smart Agriculture is a comprehensive approach that integrates productivity enhancement, resilience building, and greenhouse gas mitigation with efficient resource use and ecosystem conservation. It involves adopting innovative practices, supporting policies, and engaging communities to create a more sustainable and resilient agricultural system in the face of climate change.

Climate Smart Agriculture (CSA) is a holistic approach designed to address the challenges of climate change in agriculture. It focuses on three main objectives:

1. **Enhancing Productivity:** CSA aims to increase agricultural output and farmers' incomes while maintaining or improving environmental sustainability.
2. **Building Resilience:** It helps farmers adapt to the changing climate by promoting practices that improve resilience to extreme weather events and shifts in climate patterns.
3. **Mitigating Emissions:** CSA seeks to reduce greenhouse gas emissions from agricultural activities and enhance carbon sequestration in soils and plants.

Features of Climate Smart Agriculture:

Climate Smart Agriculture (CSA) encompasses several key features that collectively address the challenges of climate change while aiming for sustainability and resilience in agricultural systems. Here are the primary features:

1. Productivity Enhancement

- **Improved Crop Varieties:** Use of climate-resilient crop varieties that can withstand drought, heat, or pests.
- **Advanced Farming Techniques:** Adoption of precision agriculture, integrated pest management (IPM), and other advanced methods to boost productivity.

2. Climate Resilience

- **Adaptive Practices:** Implementation of practices that increase resilience to

climate variability, such as adjusting planting dates or using drought-tolerant crops.

- **Diversification:** Incorporation of diverse crops and livestock to spread risk and enhance ecosystem stability.

3. Green house Gas Mitigation

- **Reduced Emissions:** Practices that lower greenhouse gas emissions from agriculture, such as improved manure management or reduced use of synthetic fertilizers.
- **Carbon Sequestration:** Techniques like agroforestry, cover cropping, and conservation tillage that capture and store carbon in soil and vegetation.

4. Resource Efficiency

- **Water Management:** Efficient irrigation systems (e.g., drip or sprinkler irrigation) and rainwater harvesting to optimize water use.
- **Nutrient Management:** Use of organic fertilizers, composting, and precise application techniques to enhance nutrient use efficiency and reduce runoff.

5. Soil Health Improvement

- **Soil Conservation:** Practices such as no-till farming, cover cropping, and contour plowing to prevent soil erosion and degradation.
- **Organic Matter Addition:** Use of organic amendments to improve soil structure, fertility, and water retention.

6. Ecosystem Services

- **Biodiversity Enhancement:** Promotion of biodiversity through crop rotations, agroecological practices, and maintaining natural habitats.
- **Pollinator Support:** Protection and encouragement of pollinator populations through diverse plantings and reduced pesticide use.

7. Economic Viability

- **Cost-Effective Solutions:** Adoption of cost-effective practices that enhance profitability and reduce financial risk.
- **Market Access:** Support for farmers to

access markets and value chains that reward sustainable practices.

8. Knowledge and Innovation

- **Research and Development:** Continuous innovation in practices and technologies through research and extension services.
- **Farmer Training:** Education and training programs to equip farmers with knowledge and skills to implement CSA practices.

9. Policy and Institutional Support

- **Enabling Policies:** Development of policies and incentives that support the adoption of CSA practices.
- **Institutional Framework:** Strong institutional support for research, extension services, and farmer networks.

10. Community Engagement

- **Participatory Approaches:** Involvement of local communities in decision-making and implementation processes to ensure practices are locally relevant and culturally appropriate.
- **Knowledge Sharing:** Platforms for sharing experiences and best practices among farmers and stakeholders.

Climate Smart Agriculture (CSA) is an approach that aims to increase productivity while reducing greenhouse gas emissions and enhancing resilience to climate change. This concept can be applied to various agricultural practices, including horticulture. Here's a breakdown of how CSA, including horticulture, can contribute to sustainable development:

Principles of Climate Smart Agriculture

1. **Productivity:** Increase farm productivity and incomes in a sustainable manner.
2. **Adaptation:** Enhance resilience and adaptive capacity to climate change.
3. **Mitigation:** Reduce greenhouse gas emissions and increase carbon sequestration.

CSA in Horticulture

Horticulture involves the cultivation of fruits, vegetables, nuts, seeds, herbs, sprouts, mushrooms, algae, and non-food crops like flowers and grass. Integrating CSA practices into

horticulture can be particularly effective due to the high value and diversity of horticultural crops. Here's how CSA can be applied:

1. Soil Management:

- **Organic Matter:** Incorporate compost and organic matter to improve soil health and carbon sequestration.
- **Cover Crops:** Use cover crops to prevent soil erosion, enhance soil fertility, and increase water retention.

2. Water Management:

- **Efficient Irrigation:** Adopt drip or sprinkler irrigation systems to minimize water waste.
- **Rainwater Harvesting:** Collect and store rainwater for use during dry periods.

3. Pest and Disease Management:

- **Integrated Pest Management (IPM):** Use a combination of biological, physical, and chemical methods to control pests and diseases with minimal environmental impact.
- **Resistant Varieties:** Grow crop varieties that are resistant to pests and diseases.

4. Crop Selection and Diversity:

- **Diverse Cropping Systems:** Grow a mix of crops to reduce risk and improve resilience against climate-related stresses.
- **Climate-Resilient Varieties:** Select crop varieties that are better suited to changing climate conditions.

5. Energy Efficiency:

- **Renewable Energy:** Utilize solar, wind, or other renewable energy sources to reduce reliance on fossil fuels.
- **Energy-Efficient Equipment:** Invest in energy-efficient tools and machinery.

6. Waste Management:

- **Recycling and Reuse:** Recycle plant waste and use it for composting or mulch.
- **Waste Reduction:** Minimize waste throughout the supply chain from production to consumption.

Benefits of CSA in Horticulture

1. **Enhanced Productivity:** Improved soil

health, efficient water use, and pest management can lead to higher yields and better quality produce.

2. **Increased Resilience:** Diverse cropping systems and climate-resilient varieties help mitigate risks associated with extreme weather events.
3. **Lower Emissions:** Efficient use of resources and improved management practices can reduce the carbon footprint of horticultural operations.
4. **Economic Viability:** Higher productivity and reduced costs can improve the profitability of horticultural enterprises.
5. **Environmental Protection:** CSA practices contribute to the conservation of natural resources, biodiversity, and ecosystem services.

Climate Smart Agriculture (CSA) is essential for several reasons

1. **Climate Resilience:** CSA helps farmers adapt to unpredictable weather patterns and extreme events by improving soil health, water management, and crop diversity.
2. **Sustainable Productivity:** It aims to increase agricultural productivity while reducing environmental impacts, ensuring food security for a growing population.
3. **Mitigation of Emissions:** CSA practices help lower greenhouse gas emissions from farming activities, contributing to climate change mitigation efforts.
4. **Resource Efficiency:** It promotes efficient use of resources like water and nutrients, reducing waste and conserving natural resources.
5. **Economic Stability:** By improving resilience and productivity, CSA can enhance the economic stability of farming communities, reducing risks associated with climate variability.

Challenges and Considerations

1. **Knowledge and Training:** Farmers may need training and support to adopt CSA practices effectively.
2. **Initial Costs:** Some CSA practices may require upfront investment, which could be a

barrier for smallholder farmers.

3. **Access to Resources:** Availability of resources like quality seeds, irrigation technology, and market access can influence the success of CSA implementation.

Moving Forward

To promote CSA in horticulture, it is crucial to support research and development, provide training and extension services, and facilitate access to technology and financial resources. Collaboration between governments, NGOs, research institutions, and private sector players is essential to create an enabling environment for CSA practices to thrive.

By integrating CSA principles into horticulture, we can advance towards more sustainable agricultural systems that are resilient to climate change and contribute positively to economic and environmental goals.

Climate Smart Agriculture and Sustainable Agriculture: Climate Smart Agriculture (CSA) and Sustainable Agriculture share overlapping goals but differ in their focus and approach:

Climate Smart Agriculture (CSA)

1. Objectives:

- **Productivity:** Enhance agricultural productivity and income.
- **Resilience:** Increase resilience to climate change impacts.
- **Mitigation:** Reduce greenhouse gas emissions and enhance carbon sequestration.

2. Approach:

- **Climate Adaptation:** Focuses on adapting farming practices to changing climate conditions.
- **Emission Reduction:** Targets reduction of agriculture-related emissions.
- **Resource Efficiency:** Promotes efficient use of water, soil, and nutrients.

3. Key Practices:

- Use of climate-resilient crop varieties.
- Efficient irrigation systems and water management.
- Carbon sequestration practices like agroforestry.

Sustainable Agriculture:**2. Objectives:**

- **Environmental Health:** Protect and enhance environmental quality.
- **Economic Viability:** Ensure farm profitability and economic stability.
- **Social Equity:** Improve the quality of life for farmers and communities.

3. Approach:

- **Resource Management:** Emphasizes long-term health of natural resources.
- **Ecosystem Balance:** Focuses on maintaining ecological balance and biodiversity.
- **Social Considerations:** Addresses social and economic aspects of farming.

4. Key Practices:

- Organic farming and reduced chemical use.
- Soil conservation and biodiversity enhancement.
- Fair labor practices and community engagement.

Intersection and Synergies:

- **Overlap:** Both CSA and Sustainable Agriculture aim to enhance productivity, maintain environmental health, and support farming communities.
- **Complementary Goals:** CSA's focus on climate adaptation and emission reduction complements the broader environmental and social goals of Sustainable Agriculture.

In essence, CSA can be seen as a subset of Sustainable Agriculture with a specific emphasis on addressing climate change, while Sustainable Agriculture encompasses a broader range of practices focused on overall environmental, economic, and social sustainability.

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VALUE ADDITION OF TOMATOES AND POST-HARVEST TECHNOLOGY- A REVIEW

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Abstract

Tomato is called as “Poor man’s orange” due to good source of vitamin A, B and excellent source of vitamin C. It adds variety of colour and flavor to the food and also rich in medicinal values. The objective of our research is to development of different value-added products form tomato and analysis of quality parameters. Quality parameters for different value-added products from tomato like moisture content, ash content, bulk density, tapered density, flowability, Carr index, swelling capacity and sensory evaluation of different value-added product from tomato was analysed. The highest moisture content was observed in tomato jam (27.16%) followed by instant tomato rasam mix (4.67%), instant tomato sauce powder (4.6%), instant tomato pickle mix (4%) and instant tomato ketchup mix (3.37%) and from the sensory evaluation results, it was observed that higher sensory score for tomato jam (9.33) followed by instant tomato ketchup mix (9.0).

Keywords: tomato, postharvest losses, value addition, constraints.

Introduction

The word “tomato” may refer to the plant (*Solanum lycopersicum*) or the edible, typically red, fruit that it bears. Originating in South America, the tomato was spread around the world following the Spanish colonization of the Americas, and its many varieties are now widely grown. The tomato belongs to the nightshade family. The plants typically grow to 1–3 meters (3–10 ft) in height and have a weak stem that often sprawls over the ground and vines over other plants. It is a perennial in its native habitat, although often grown outdoors in temperate climates as an annual. The tomato is now grown worldwide for its edible fruits, with thousands of cultivars having been selected with varying fruit types and for optimum growth in differing growing conditions. Cultivated tomatoes vary in size, from tom berries, about 5 mm in diameter, through cherry tomatoes, about the same 1–2 centimeters (0.4–0.8 in) size as the wild tomato, up to beefsteak

tomatoes 10 centimeters (4 in) or more in diameter. The most widely grown commercial tomatoes tend to be in the 5–6 centimeters (2.0–2.4 in) diameter range. Most cultivars produce red fruit, but a number of cultivars with yellow, orange, pink, purple, green, black, or white fruit are also available. Multicolored and striped fruit can also be quite striking. Tomatoes grown for canning and sauces are often elongated, 7–9 centimeters (3–4 in) long and 4–5 centimeters (1.6–2.0 in) diameter; they are known as plum tomatoes, and have lower water content. Tomato is an important vegetable grown universally because of its nutritional values. The production requires a high level of management, labour intensive and bulk of production is mostly supported by small family farm. Despite its importance to human food, tomato is highly perishable resulting to poor quality and nutritional value of fresh tomato and consequently decreases in farmers’ income. however, stated that perishability of tomato is

often affected by postharvest and storage practices.

Nutritional value of tomato

Tomatoes are nutritious and low in calories. One medium sized tomato provides 57 per cent of Recommended Daily Allowances (RDA) of vitamin C, 25 per cent RDA of vitamin A and 8 per cent RDA of iron, yet it has only 35 calories. Besides being eaten fresh, the versatile tomato can be baked, stewed, fried, juiced or pickled and can be used in soups, salads and sauces. The composition and nutritive value of tomatoes and its products are given in the Table 1. Tomatoes are now eaten freely throughout the world, and their consumption is believed to benefit the heart, among other organs. They contain the carotene lycopene, one of the most powerful natural antioxidants. In some studies, lycopene, especially in cooked tomatoes, has been found to help prevent prostate cancer, lycopene has also been shown to improve the skin's ability to protect against harmful UV rays. A study done by researchers at Manchester and Newcastle universities revealed that tomato can protect against sunburn and help keeping the skin looking youthful. Natural genetic variation in tomatoes and their wild relatives has given a genetic plethora of genes that produce lycopene, carotene, anthocyanin and other antioxidants.

Post harvest losses of tomatoes

Tomato being a climacteric fruit, the start of ripening is accompanied by a rapid rise in respiration rate called 'respiratory climacteric' during which oxidative breakdown of complex substrates occur, ageing follows, leading to product deterioration. Also, tomatoes being fleshy fruits, continue to lose water after harvest. This results in a wilted, dull appearance that reduces the eye appeal and freshness and eventually becomes unmarketable. Losses in quantity and quality occur between harvest and consumption. Primary factors responsible for post-harvest produce losses include poor pre-harvest measures, adoption of poor production techniques (varieties with low shelf-life, imbalance use of nutrients, insect pest and disease infestation and abiotic stresses), non-application of pre harvest recommended treatments/practices, harvesting at

improper stage and improper care at harvest and post-harvest problems, non-removal of field heat, dumping produce, moisture condensation causing pathogen infestation, packaging in bulk without sorting and grading of produce, improper transportation and storage and distant and time consuming market distribution. These losses bring low return to growers, processors and traders and country also suffers in terms of foreign exchange earnings (Kader, 1992). Evidence suggests that these losses tend to be the highest in those countries where the need for food is greater; some authorities put post-harvest losses of sweet potatoes, tomatoes, bananas and citrus fruit sometimes as high as fifty per cent (FAO, 2002).

Physiological disorders

Chilling injury: Tomatoes are chilling sensitive at temperatures below 10°C (50°F) if held for longer than 2 weeks or at 5°C (41°F) for longer than 6-8 days. Consequences of chilling injury are failure to ripen and develop full colour and flavour, irregular (blotchy) colour development, premature softening, surface pitting, browning of seeds, and increased decay (especially black mold caused by *Alternaria* spp.). Chilling injury is cumulative and may be initiated in the field prior to harvest.

Physical disorders: Tomatoes are sensitive to many production and environment-genetic interaction disorders which may be manifested during postharvest ripening or postharvest inspection. Fertilizer and irrigation management, weather conditions, insect feeding injury, asymptomatic virus infection and unknown agents may interact to affect postharvest quality. Examples are blossom end rot, internal white tissue, rain checking, concentric and radial cracking, puffiness, persistent green shoulder and Gray wall.

Pathological disorders: Diseases are an important source of postharvest loss depending on season, region and handling practices. Commonly, decay or surface lesions result from the fungal pathogens *Alternaria* (Black Mold rot), *Botrytis* (Gray Mold rot), *Geotrichum* (Sour rot) and *Rhizopus* (Hairy rot). Bacterial soft rot caused by *Erwinia* spp. can be a serious problem particularly if proper harvest and packinghouse sanitation is not used. Treatment with hot air or hot water immersion (55°C for 0.5 - 1.0 min.) has been

effective in preventing surface Mold but has not been used extensively for commercial treatments. CA can be effective in delaying fungal growth on the stem end and fruit surface. Greenhouse tomatoes marketed on-the-vine ("cluster tomatoes") is very susceptible to Botrytis Gray Mold, especially if film-wrapped in a tray.

Post harvest technology: Tomato is an important dietary source of vitamins and minerals. A major problem with the storage and marketing of fresh tomatoes is their relatively fast deterioration in quality and short shelf life. Hence, different post-harvest technologies are employed in reducing the losses and extending the shelf-life. Tomatoes are harvested at various stages of ripeness and the storage conditions employed differ with each stage. Rapid cooling soon after harvest is essential for optimal postharvest keeping quality. The pre-cooling endpoint is typically 12.5°C (55°F). Forced-air cooling is the most effective practice but room cooling is more common. Placing containers of warm tomatoes in a refrigerated space, known as room cooling, is recommended. To aid room cooling and prevent the buildup of heat of respiration, containers of tomatoes should be loosely stacked with space between the containers to allow for sufficient air circulation. In general pre-cooling is required only if the fruit temperature is higher than 26-27°C and ripening is to be delayed. Although fully ripe tomatoes may be held at 2-5°C for a few days prior to consumption (not longer, since colour loss and softening may occur), fruit that are mature green or at the turning or breaking stage should not be subjected to temperature lower than 12°C as chilling injury may occur, with adverse consequence for subsequent ripening and quality.

Harvest: The objective of harvesting is to pick the fruits at the proper stage of maturity, with a minimum damage, as rapidly as possible and at a minimum cost best achieved by hand harvesting in most fruits and vegetables. Harvesting can be done by hand and by mechanical means which have their merit and demerit. Tomatoes are usually harvested manually by twisting the fruits with thumb and finger and retain calyx with the fruits. Avoid any injury to fruit. Harvesting should be done either in the early morning hours or in the evening hours.

Grading: During grading of fruits, damaged, rotten and cracked fruits should be removed. Only healthy, attractive, clean and bright fruits should be selected. The grades are mostly based on the condition and the quality of the fruits and not specifically on their size. However, on the basis of the size of the fruits three grades are formed: small (255 g). Retailers normally do size grading for the local market. Internal urban markets have differential prices for size grades as against ungraded fruit. Bureau of Indian Standards has specified 4 grades viz., Super A, Super, Fancy and Commercial for tomato crop. By using equipment's, tomatoes are typically separated by size on one or more sizing belts. A rotating bar grader may be suitable alternative for the small producer. It is important on such a line that the belt and roller speed and the drop height be minimized and that all impact surfaces be well padded. A layer of 3/8- to 1/2-inch closed-cell foam with a smooth, washable outer surface should be adequate. Open-cell foam or scraps of carpeting are better than nothing but are very difficult to keep clean and generally do not provide the proper level of protection.

Storage: The main objective in storage after harvest is to control the rate of ripening to extend the marketing period. As the tomatoes are chilling sensitive, the recommended storage temperatures differ depending on the fruit maturity. A storage temperature of 13°C with 90-95 per cent relative humidity is recommended for slow ripening. At this temperature, most varieties keep in good condition for 2-3 weeks and change colour very slowly. In cold storage, unripe tomatoes can be stored for 4 weeks at a temperature of 8-10°C with 85-90 per cent relative humidity. Fully ripe fruits are stored at 7°C with 90 per cent relative humidity for 1 week.

Ethylene treatment: Ethylene is a naturally occurring, odourless, tasteless gas produced by many types of produce, including tomatoes. Mature green tomatoes exhibit accelerated ripening in the presence of ethylene. In commercial practice, mature green tomatoes are exposed to supplemental ethylene treatment to hasten ripening and to ensure uniform ripening throughout a lot. Tomatoes may be exposed to an ethylene concentration of 100 to 150 ppm for 24 to

48 hours at a temperature of 70 to 75° F and 90 per cent relative humidity. Immature tomatoes may be ripened with the application of ethylene, but the resulting fruit will not be of good quality.

Controlled or modified atmospheres storage: Controlled or modified atmospheres have been shown to delay ripening during storage. Batu (2003) observed that after 60 days storage of mature green or rose tomatoes at 13 or 15°C, those stored under controlled atmospheres of 5.5% O₂ + CO₂ (3.2, 6.4 or 9.1%) were less acceptable in terms of sweetness and aroma than those stored in air. Moreover, even short-term storage of red, almost fully ripe tomatoes under conditions of low or zero O₂ (e.g. in N₂ for 35 hours) adversely affects fruit aroma, due to a reduction in C-6 compounds and isobutyl thiazole and an increase in ethanol and acetaldehyde (Bou kobza and Taylor, 2002).

Packaging: There are different modes of packaging. Generally, container-packing is considered ideal for packing fruits or vegetables because these are easy to handle, provide good protection from mechanical damage, have adequate ventilation and convenient for merchandising. They could easily carry printed information about the product packed and are helpful in advertising about the product. Fancy containers such as fibre board boxes, or wooden or plastic crates, are often used for high-value products. Inexpensive containers such as bamboo baskets or nylon net sacs are commonly used for low-priced products. CFB cartons offer available alternative to the traditional wooden boxes. Apart from this, polyethylene bags (PE), corrugated container box with a General-Purpose Polystyrene (GPPS) liner, Polystyrene (PS) trays, expanded PS trays and Polyethylene Terephthalate (PET) clamshell container and transported in bulk within a corrugated containers are used. Tomatoes harvested at breaker stage and packed in 300-gauge polyethylene bags with three vents recorded minimum changes in moisture, total soluble solids, acidity and sugars than the control fruits.

Processing of tomatoes: Main objective of tomato processing is to supply wholesome, safe, nutritious and acceptable food to consumers. Tomatoes and tomato-based foods are low in

calories and possess antioxidant micronutrients. Tomato is a valuable raw material for processed products such as ketchup, sauce, juice, soups etc. The recent scientific advances have revolutionized tomato processing industries. Tomato products have good export potential especially in the Middle East. Tomato in India occupies second position amongst the vegetable crops in terms of production. Another encouraging trend has been that India's production level of processed tomato has risen by 50 per cent. The main objective of processing is to supply wholesome, safe, nutritious and acceptable food to consumers throughout the year. Tomatoes and tomato-based foods are considered healthy for the reason that they are low in calories, but possess a remarkable combination of antioxidant micronutrients. A number of tomato products e.g. ketchup, juice, puree, paste, sauce, pickles are available in the market.

Value added tomato: Value addition is the most suitable process to use and form the bulk of tomato. The demand for tomato processing is more because there is a need to preserve the product for cooking purposes out of season or to add value for extra income. The most important methods of preparing value added products are concentration (to a paste or purée) and drying either fruit pieces or making to a powder. High quality 'salad' tomatoes fetch the highest value when sold fresh and in good condition.

Tomato products:

The processed tomato can be divided into the following end user categories:

- Peeled tomatoes
- Concentrate
- Tomato pulp
- Tomato paste
- Dehydrated tomatoes
- Tomato powder
- Ketchup
- Tomato juice, strained tomatoes and diced tomato.

Cultivars suited for processing: Roma (Indian Agricultural Research Institute) prolific bearer, determinate, good foliage cover, excellent bearing, elliptical fruit shape with yellow stem end fruits thick at stem end. Punjab Chhuhara (Punjab Agricultural University) – determinate,

good foliage cover, profile bearer, fruits elliptical in shape with yellow stem end. S 152 (Indian Agricultural Research Institute) – prolific bearer, determinate, good coverage, fruits egg shaped with yellow stem end, borne in bunches, suitable for canning and long-distance transportation. It is known as all-purpose variety and known as Pusa Gaurav. Studies on tomato cultivars for processing industry revealed that NDT 120, Pant Bahar and NDT 101 were highly suitable for the production of quality juice, ketchup and chutney, respectively.

Raw material quality: Tomatoes should be ripe, red and firm to soft, free of all mould growth (by cutting out infected parts) and free of stems, leaves, dirt and other soils (by washing). It is less important if the tomatoes have surface blemishes or splits/cracks (provided these are not infected) and in most processes they will be cut or pulped.

1. **Tomato Powder:** Tomato powder is simply dehydrated tomatoes that have been finely ground. It can be used as a spice, seasoning and garnish.
2. **Tomato Pulp:** Tomato pulp is prepared from ripe tomatoes in the same manner as tomato juice. Cooking for pulp concentration can be done in an open cooker or a vacuum pan.
3. **Tomato Puree:** Tomato puree can be defined as concentrated tomato juice or pulp without skin and seeds and containing not less than 25 per cent of tomato solids. Tomato puree can be defined as concentrated tomato juice or pulp without skin and seeds and containing not less than 25 percent of tomato solids.
4. **Tomato juice:** Plant ripe, fully red coloured fruits are selected and all green, blemished and over-ripe fruits are discarded. A good quality juice should be of deep red colour, possess the characteristic taste and flavour of tomato, contain about 0.4 per cent acid (in terms of citric acid), be uniform in appearance and have high nutritive value. In addition, the juice should contain 0.5 per cent salt, 15 per cent sugar. For the production of 1 liter of juice, 10 g of sugar, 5 g of salt, 1 g of citric acid and 1 g of sodium benzoate should be added. Tomato juice/pulp can be extracted by hot or cold pulping. Hot pulping is superior to cold pulping because of easy extraction of juice besides higher yield, less oxidation of vitamin

C and less chances of microbial spoilage. On commercial scale, a pulper or continuous spiral press is used for juice extraction but in homes tomatoes are strained through a steel sieve. The juice is heated upto 82-88°C for 2 minutes and hot filled in bottles. Then the bottles are sterilized and cooled.

5. **Tomato sauce/ ketchup:** It is made from strained tomato juice or pulp with the addition of spices, salt, sugar and vinegar (onion and garlic are added optionally) and contains not less than 12 per cent tomato solids and 25 per cent total solids. About one-third of the total sugar required is added at the time of commencement of boiling to intensify and fix the red tomato colour. If the whole quantity of sugar is added initially, the cooking time will be longer and the quantity of pulp will be adversely affected. Generally, the sugar content in ketchup/sauces varies from 10-26 per cent. These do not adversely affect the colour of the product and are generally added a few minutes before the end of cooking. The salt content of the product should be 1.3-3.4 per cent. Good quality vinegar is essential for the preparation of high-quality sauce/ketchup. It should contain 5.0-5.5 per cent acetic acid and should be added when the product has thickened sufficiently, so that the acid is not lost by volatilization. Tomato sauce/ketchup generally contains 1.25-1.5 per cent acetic acid. Sometimes glacial acetic acid (100 % acetic acid) is used which is colourless and cheaper than vinegar.
6. **Quality evaluation of processed tomato products:** Quality makes a product what it is. It is the combination of attributes or characteristics of a product that have significance in determining the degree of acceptability of the product to a user and that determines its value or worth. As used by the industry, it is a concept involving degree: degree of purity, strength, flavour, colour, size, maturity, workmanship, condition and any other distinctive attribute or characteristic of the product. Thus, the term quality, without being defined in terms of some standard, means little. The trade also uses the term to mean the finest product

attainable. From past experience food processors have learned that high-quality products never fail to sell. This is true because the consumer recognizes the brands that maintain their quality at the standard set for that particular product. Many large companies attain their position by the control of quality of the products they process.

Opportunities

- Large production and material base offers vast potential for tomato processing activities
- Creating awareness for processed tomato products
- Ensuring safety
- Developing techniques to meet the export potential of processed tomato products.

Challenges

- Competition from global players
- Loss of trained manpower to other industries and other professions due to better working conditions prevailing there may lead to further shortage of manpower.
- Rapid developments in contemporary and requirements of the industry may lead to fast obsolescence.

Conclusion

Tomato is one of the most researched horticultural crops. The tomato is the second largest vegetable crop in the world after potatoes and a significant source of lycopene. In the food industry, tomatoes serve multiple applications. Tomatoes are climacteric fruits that contain a lot of compounds that are good for health. The chemical composition of tomatoes varies depending on their variety and the growing season. In addition to being a healthy food with little calories, tomatoes are -based products like tomato juice. Tomatoes, including their skins and seeds, could help greatly to increase the consumption of antioxidants in the average person's diet. Tomatoes are consumed fresh and processed, primarily as tomato puree, paste, ketchup, and juice. The effect of nutrition on fruit quality is likely to be a growing area of interest in future research in the tomato nutrition field.

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A REVIEW STUDY: BACTERICIDAL PROPERTIES OF GANODERMA LUCIDUM

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Abstract

In recent years, there has been a notable surge in the global interest in edible herbs for health care and promotion. Because of its many beneficial secondary metabolites, *Ganoderma lucidum* is a woody-textured forest fungus that has been utilized since ancient times to improve health and prevent and treat a variety of ailments. Numerous cellular mechanisms, including those related to increased cellular immunity, anti-viral, anti-bacterial, anti-cancer, and antioxidant activity, have been postulated thus far to explain the actions of the active metabolites and the health and hygienic qualities of this important medicinal fungus. The scientific literature on the antibacterial qualities of the therapeutic fungus *G. lucidum* is reviewed in this article.

Keywords: *Ganoderma lucidum*, Secondary metabolites, Antimicrobial.

Introduction

Tanase (2017) states that out of the 10,000 or more known species of fungi globally, only approximately 300 are known to have therapeutic uses. Around the world, traditional medicine has long recognized and employed fungi as medicinal agents (Sharma, 2019). According to Lee et al. (2016), fungi constitute a rich source of physiologically active substances. Although scientific and technological developments in the modern era have benefited human health, there is still a need to look into better natural and organic alternatives with less negative consequences. A common basidiomycete fungus used in traditional medicine and as a medicinal fungus in China, Japan, and many other nations, particularly Asian countries, is *Ganoderma lucidum*, also known as “Lingzhi” in Chinese and “Reishi” in Japanese (Gil et al., 2016; Sanodia et al., 2009; Wachtel et al., 2004). More than 2000 years have passed since this medicinal mushroom was originally included in the antiquated encyclopedia “Shen Nong’s Ben Cao Jing” (Batra et al., 2013; Chiu et al., 2017). Chinese physicians are aware of red ganoderma as

an immortality-granting fungus. This healing fungus grows naturally on decaying tree trunks. When the bean-shaped mushrooms are young, their yellowish-brown, reddish-yellow bodies become darker with age. Products derived from *G. lucidum* are currently highly regarded in the global mushroom market and come in a range of forms, such as supplements, powders, and teas made from spores, fruits, and mycelium (Lindequist et al., 2005). As a member of the basidiomycete’s branch, *G. lucidum* possesses a wide range of biologically active substances, such as polysaccharides (mannitol, β -glucan), alkaloids, triterpenoids (ganodric acid), sterols, amino acids, proteins, and other substances that give the fungus its many therapeutic qualities (Paterson, 2006). The therapeutic fungus *G. lucidum* has yielded more than 140 triterpenoids to date, and several novel compounds are still being discovered (Sudheer et al., 2016; Weng et al., 2010, 2011). Current pharmacological and clinical studies have revealed that *G. lucidum* possesses several therapeutic benefits. Among them, the most significant substances generated by *G. lucidum* are polysaccharides and triterpenoids,

particularly ganoderic acid, which contain a variety of significant therapeutic properties like antioxidants (Krishna *et al.*, 2016; Gill *et al.*, 2016), treatment of type 2 diabetes (Rezghi, 2018; Liang *et al.*, 2010) immune system balancer (Ishimoto *et al.*, 2017), liver protection (Ren *et al.* 2010; Lee *et al.*, 2016), neuroprotection (Zhao *et al.*, 2019), histamine inhibition (Yu *et al.*, 2013), cardiac protection (Rajasekaran *et al.*, 2012; Zeng *et al.*, 2018), anti-inflammatory (Cai *et al.*, 2017), anti-allergy (Ji *et al.*, 2007), Anti-viral (Wang *et al.*, 2004), anti-cancer (Zolj *et al.*, 2018; Gurovic *et al.*, 2018; Ahmad, 2020), Anti- arthritis, (Pan *et al.*, 2017), anti-HIV (Akbar *et al.*, 2011; Kang *et al.*, 2015; Seo & Choi, 2021), antibacterial (Sarnthima *et al.*, 2017; Quereshi *et al.*, 2010), anti-fungal (Geng *et al.*, 2017; Nayak *et al.*, 2010), anti-osteoporotic (Elhassaneen *et al.*, 2016), anti-androgenic (Fujita *et al.*, 2005), antinociceptive (Sheena *et al.*, 2005), and many other. Bacteria are a group of prokaryotes. These organisms, which are mostly several microns in size, are among the most diverse and important microorganisms. Because bacteria and living things coexist largely, life on Earth would not function as it does without them. Generally speaking, only a tiny portion of bacteria are harmful and can result in infectious illnesses like cholera, TB, anthrax, leprosy, plague, etc. Antibiotics are used in modern medicine to treat and prevent bacterial infections. A virus is a tiny pathogen that can only reproduce within an organism's live cells. All living things, including bacteria and plants as well as animals and plants, are susceptible to viral infection. Viruses can infiltrate the host body and use its cells for replication. The only protection we have against viruses is our immune system, unlike bacteria, which can be eradicated with antibiotics. These conditions may seem worrisome, but some measures can help boost the immune system and help viral infections heal faster. The stronger the immune system is able to detect and fight viruses, the milder the symptoms of the disease.

Managing diseases caused by bacteria and viruses. Finding substances that precisely block bacterial and viral activity while sparing healthy cells is the aim of research into the treatment of viral and bacterial infections. Researchers are searching medicinal plants for novel antibacterial,

antifungal, and antiviral medicines in response to the negative side effects of antibiotics and the rise of mutant and resistant species. (Xiao and Zhong, 2009). *G. lucidum* was injected orally into laboratory mice during an experiment, however no harm to normal body cells was seen. Antibacterial chemicals from *G. lucidum* have been shown in multiple investigations to be effective against both gram-positive and gram-negative bacteria (Ferreira *et al.*, 2015; Sakthivigneswari *et al.*, 2013) Significant antibacterial activity is exhibited by *G. lucidum* polysaccharide components (Smania *et al.*, 2007). Numerous studies have demonstrated the broad spectrum of antibacterial action of several substances, including triterpenoids, ganomycin, and others (Gao *et al.*, 2003; Suay *et al.*, 2000; Shah *et al.*, 2014). Antibiotic capabilities have been demonstrated by *G. lucidum* extracts, which have been demonstrated to suppress the growth of both gram-positive and gram-negative bacteria (Gao *et al.*, 2003). Researchers have tested *G. lucidum* extracts against a range of microorganisms, such as *Bacillus subtilis* and *Escherichia coli*. They noted varying degrees of antibiotic action against *Salmonella* sp., *Enterobacter aerogenes*, *Corynebacterium diphtheria*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. Sheena *et al.* (2003); Shah *et al.* (2014); Kamble *et al.* (2011); Singh *et al.* (2014). Research revealed that the extract extracted from *Ganoderma lucidum* inhibits *Helicobacter pylori*, which is responsible for gastric ulcer formation and other gastric complications (Suay *et al.*, 2000). Different *G. lucidum* extracts were examined in a different investigation. Selected among them were *Escherichia coli*, *Bacillus cereus*, *Staphylococcus aureus*, *Enterobacter aeruginosa*, and *Pseudomonas aeruginosa*, against which methanolic extract from *G. lucidum* exhibited antibacterial action. In Siwulski *et al.* (2015) and Gaylan *et al.* (2018). In a study, (Heleno *et al.* 2013) looked at how well *G. lucidum* extracts and several medications worked against various microorganisms. They discovered that *G. lucidum* extracts outperformed ampicillin and streptomycin in their ability to inhibit *Staphylococcus aureus* and *B. cereus*. Additional studies have demonstrated the synergistic effects of ampicillin, oxytetracycline, cefazolin, and

chloramphenicol with *G. lucidum* extract. Additionally, it has been demonstrated that several *G. lucidum* preparations are as effective against bacteria as gentamicin sulfate (Dulger et al, 2004; Quereshi et al, 2010). Some species of *G. lucidum* have been shown to inhibit the growth of methicillin-resistant *Staphylococcus aureus* by producing ganomycin. (Mothana et al, 2000). It has been demonstrated that *G. lucidum* possesses antifungal activity, and several antifungal compounds have been extracted from the plant (Naveenkumar et al, 2018; Sanodiya et al, 2009). It has been demonstrated that ganodermin derived from *ganoderma* inhibits the growth of *Physalospora piricola*, *Botrytis cinerea*, and *Fusarium oxysporum*. One of the most prevalent oral fungi that cause candidal infections of the mouth is *Candida albicans*. Various quantities of *G. lucidum* were evaluated in an in vitro investigation against *Candida albicans*, and the results demonstrated antifungal effects against *Candida albicans* (Nayak et al, 2010). Research is being done extensively to find antiviral drugs that precisely stop the virus from spreading while without interfering with the body's normal process of cell division. The antiviral activity of substances extracted from extracts of the medicinal fungus *G. lucidum* was shown in a study by (Eo et al., 1999). Five compounds that were isolated from *G. lucidum* demonstrated a considerable ability to prevent the cytopathic effects of both HSV (herpes simplex) and VSV (vesicular stomatitis virus). Research conducted in laboratories has demonstrated the antibacterial efficacy of polysaccharides and triterpenoids against the hepatitis B, HIV, and Epstein-Barr viruses (EBV). Another study (Li and Wang, 2006) found that ganoderic acid extracted from *G. lucidum* had inhibitory effects on the replication of the hepatitis B virus over an 8-day period. *Ganoderma* metabolites that were isolated exhibited anti-herpes properties. *G. lucidum*'s prophylactic activity against the vesicular stomatitis virus (VSV), herpes simplex virus type 1 (HSV-1), and herpes simplex virus type 2 (HSV-2) was proven by aqueous and methanolic extracts. Herpes simplex virus type 1 (HSV-1) and herpes simplex virus type 2 (HSV-2) are the two herpes viruses that cause herpes simplex. Herpes simplex virus 1 (HSV-1) and herpes simplex virus 2 (HSV-2) are both

powerfully inhibited by *G. lucidum* (Liu et al., 2004; Kim et al, 2000; Oh et al, 2000). Proteoglycans isolated from *G. lucidum* mycelium were found to have inhibitory effects on HSV-1 and HSV-2 in a different investigation (Liu et al, 2004; Li et al, 2005; Wachtel-Galor et al, 2011). A Zheng et al., 2017 research demonstrated the ability of five terpenoids derived from *G. lucidum* to prevent the Epstein-Barr virus (EBV) infection linked to Nasopharyngeal cancer (NPC): ganoderic acid A, ganoderic acid B, ganodrol B, ganodermanontriol, and ganodermanondiol. As a telomerase inhibitor, ganoderic acid B, a triterpene extracted from *G. lucidum*, has been demonstrated to prevent Epstein-Barr virus (EBV) antigens from being activated. According to several studies, ganoderic acid B is also a reasonably active inhibitor of HIV-1 protease (Zhou et al, 2018; Zheng et al, 2017). Fig 2.

HIV (human immunodeficiency virus) prevention initiatives



Fig. 1 Images of the medicinal fungus *G. lucidum*.

The human immunodeficiency virus (HIV) is the immune system's culprit behind AIDS, also known as acquired immune deficiency syndrome. The illness is referred to as the "global epidemic," and it is now spreading rapidly. An estimated 3 million individuals pass away from AIDS-related illnesses annually. HIV infection causes Immune Deficiency Syndrome (AIDS), which has grown to be a significant social and medical issue (Kartikian

et al., 2007; Paydary et al., 2013). The HIV virus infects and impairs the immune system in addition to weakening T lymphocytes, the body's defense cells, which ultimately results in AIDS. The body cannot fight infections or eradicate cancer cells without T cells, which are necessary for an immunological response. One of the current approaches to HIV treatment is to slow down the spread of AIDS. An efficient and popular method of treating immunodeficiency syndrome is the combination of two inverse nucleoside analog transcriptase (NRTI) inhibitors and a non-nucleoside reverse analog transcriptase (NNRTI) inhibitor as the primary treatment for HIV (Choengpanya et al., 2021; Matsushita and Kimura, 2002). Protease inhibitors (PIs) and strong reverse transcriptase (RT) inhibitors are among these medications. But the long-term effects of these medications are severely limited by the advent of hazardous and drug-resistant variations.

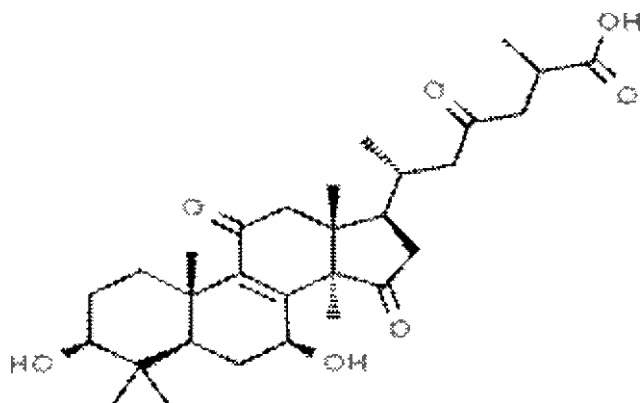


Fig. 2 Ganoderic acid B

Numerous natural compounds are effective anti-HIV medicines, according to recent investigations (Kartikian et al., 2007). Vermani and Garg (2002) noted that these substances fall into a variety of structural classes, including coumarins, flavonoids, tannins, alkaloids, lignins, terpenes, and polysaccharides. Numerous in vitro investigations have demonstrated the strong inhibitory action of *Ga. lucidum*'s triterpenoids against HIV. They have protease activity against HIV-1. In one study, an in vitro cell culture model was used to assess the anti-HIV-1 efficacy of extracts made from *Ganoderma* and *Lentinus*. The findings demonstrated that *Lentinus* and *Ganoderma* decreased the generation of primary and secondary virus transcripts by 82.1% -93.6%

and 80 to 90%, respectively, and suppressed HIV-1 replication (Flórez-Sampedro et al., 2016). The fruiting bodies of *G. lucidum* include lucidenic acid O and lucidenic lactone, which have been found to inhibit HIV-1 RT and DNA polymerase- α and - β activities. Anti-HIV-1 activity was demonstrated by ganoderic acid B and ganoderiol B, as well as numerous additional tri-tetanopenoids, such as ganoderic acid α , ganoderic acid C1, ganoderiol A, ganoderic acid H, ganodermanondiol, lucidumol B, and many more. (McKinnan et al., 2002; Gao et al., 2003; Sahar et al., 1997).

Significant anti-HIV-1 protease activity was also demonstrated by ganolosidic acid A, ganoderic acid- β , lucidomol B, ganodermanondiol, and ganodermanontriol, according to another study. (Min and associates, 1998). Of the four triterpenoids examined, ganoderic acid B shown the strongest inhibitory action against HIV-protease, according to a different study (Kang et al., 2015). According to an investigation, *G. lucidum* extracts have the ability to block HIV-1 reverse transcriptase, and the fungus's triterpenoids have significant therapeutic promise. Zhang et al. (2011) reported on this finding.

Conclusion

The demands of society are growing exponentially in every direction these days. The growing demands for healthcare and public health is one of these factors. This useful fungus, *G. lucidum*, offers a variety of therapeutic advantages that can be applied as complementary and alternative approaches to cure and prevent a wide range of illnesses. *G. lucidum* has a variety of chemical compounds, and as science progresses, we continue to learn about new substances. There are various ways in which these chemical compounds can treat the illness. As of right now, *ganoderma* has demonstrated a wide range of medicinal properties, such as antimicrobial, antiviral, antifungal, antioxidant, anti-cancer, immune-boosting, liver protection, and the ability to cure autoimmune diseases, allergies, and asthma. protection from a variety of conditions, including diabetes, obesity, Parkinson's disease, Alzheimer's disease, and many others.

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MODERN DEVELOPMENTS IN THE USE OF INORGANIC MEDIA FOR GREENHOUSE VEGETABLE PRODUCTION

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Abstract

One of the most effective substitutes for soil fumigation is soilless culture on inorganic platforms, which offers a root environment free of pathogens at planting and encourages earlier and larger harvests. Additionally, growing on substrates allows for the recycling of fertigation effluents, which helps to lessen contamination in the environment caused by fertiliser residue leaching. A high irrigation frequency may improve crop performance due to a higher availability of nutrients, specifically P and Mn, while maintaining constantly higher moisture levels in the root zone. Nutrient uptake is generally proportional to the concentration of nutrients around the roots, but in flowing solutions, plants are able to make good growth over a wide range of concentrations. Environmental factors can also have a profound effect on nutrition. With tomato and cucumber, the uptake of water, N and K were highly correlated with solar radiation and air temperature, while P uptake increased with root temperature. High humidity decreased the Ca and K contents of tomato leaves but increased the Ca content of the fruit. Increasing the salinity by adding NaCl to the solution decreased the K content of tomatoes without adversely affecting the quality.

Introduction

Growing media is used to describe the material used in a container to grow a plant. The terms 'substrate' (Schroeder, Sell, 2009; Vaughn et al., 2011) and 'rooting medium' (Blok, Verhagen, 2009) are also used as synonyms. Apart from the soils found naturally, growing media are substances that are used to cultivate plants. The right media components must be chosen in order for plant production to be successful. Organic elements like peat, compost, tree bark, and coconut might be among them. Poultry feathers, (*Cocos nucifera* L.) coir, or inorganic elements like mineral, clay, perlite, and vermiculite blends such as peat and perlite, coir and clay, and peat and wool (Grunert et al., 2008; Vaughn et al., 2011) compost (Nair & colleagues, 2011). Moreover, sand or mineral soil has been utilised in greenhouses to raise crops. For

soil-less culture, reuse of drain water or closed growing systems became obligatory. Recently, the regulation changed by shifting the focus on reaching emission targets for N rather reaching 100 % closure of the systems. Yet, recirculation is still the key issue for reaching the goal of zero emission by 2027. Instead of using soil, one might use inorganic growth media. Because soil requires pasteurisation, is heavy, and tends to compress, most greenhouse growers utilise "soilless" medium.

Preparation of inorganic media for cultivation:

Procedure: Sort the various soilless medium components vermiculite, perlite, coco peat, pot, and other materials are needed. Calculate how many components are being used. In a 3:1:1 volume by volume ratio, prepare a composite

mixture of coco peat, vermiculite, and perlite. A good compromise between physical characteristics like porosity and water-holding capacity characterises a suitable medium. Good electrical conductors: Materials containing transitional, alkali, or alkaline metals are good electrical conductors. In general, inorganic materials do not readily evaporate and are combustible and the thermal stability of inorganic materials is often high.

Horticultural vermiculite: An inorganic growth media used in greenhouse production is horticultural vermiculite. Expanded mica is a lightweight, porous substance that helps aerate soil and enhances plant roots' ability to retain water. Because of its great capacity for cation exchange, vermiculite can efficiently retain and release vital nutrients for plant development. In potting mixes and hydroponic systems, it is frequently used as a growth media on its own or as a soil addition.



Coco coir: Retention of water up to nine times its own weight in water may be retained by coco coir. In sandy or clay soils, it can aid in water retention and aid in breaking up hard soil. The drainage properties of coco coir are good. Improved oxygenation and resistance to compaction and degradation are two benefits of coco coir. The antifungal effects of coco coir are noteworthy. The pH level of coco coir is mildly acidic and by nature, coco coir is impervious to microbial invasions and decay.



Perlite: Perlite is a lightweight, inorganic mineral-based growing medium used in soilless greenhouse production. It is notable for its excellent drainage and aeration properties compared to other soilless media.



Peat moss: Peat moss is a lightweight, acidic growing medium derived from partially decomposed sphagnum moss, known for its high water-holding capacity and ability to improve soil aeration.



Zeolite media: One common filter medium used for petrol filtering is zeolite. From gases, this filter medium may eliminate ammonia, dampness, unpleasant smells, and other contaminants. Natural zeolite is able to remove moisture from an airflow because of its molecular sieve structure.



Pasteurization of greenhouse plant growing media:

Greenhouse growth media should be decontaminated by heat treatment or by treating with volatile chemicals such as methyl bromide, chloropicrin, etc. since they may include dangerous disease-causing organisms, nematodes, insects, and weed seeds.

Steam: Aerated steam can be produced by a main steam line or portable steam generator, which will destroy weed seeds and infections. Steaming should only be done after the soil has been well blended. Higher temperatures are required to destroy weed seeds, although the majority of plant diseases may be eliminated by subjecting the soil to 140°F (60°C) for at least 30 minutes.

Heat: Most organisms may be destroyed by heating the soil for 30 minutes to 180°F (82°C).

Chemicals: The soil can be treated using volatile chemicals such as chloropicrin and methyl bromide.

DMDS or dimethyl disulphide: Certain weeds, bacteria, fungus, and soilborne nematodes are poisonous to this natural product. It works well on ornamentals cultivated in fields, cucurbit crops, strawberries, blueberries, and vegetables.

Different methods used for growing plants in greenhouse:

Aeroponics: Aeroponics is a method of growing plants in a greenhouse or other structure by exposing their roots to an air or mist environment. The word “aeroponics” comes from the Latin words *aero* (air) and *ponic* (labour). This is an alternative method of soil-less culture in growth-controlled environments. The first person to study air culture cultivation was Carter (1942),

who also reported a technique for growing plants in a water mist to make root investigation easier. Carter (1942) and Went (1957) first described the air-growing method in spray culture as “aeroponics.” This technique has been applied successfully for the production of different horticultural species including lettuce, tomato, cucumber.

Hydroponics: Hydroponics is a method of growing plants without soil, using a water-based nutrient solution instead. Hydroponics allows you to control the amount of light and nutrients your plants receive, which can be beneficial for growing crops year-round. Hydroponics is a sustainable and efficient way to grow crops, and it requires less water than traditional farming methods. Hydroponics systems can use an aggregate substrate, or growing media, such as coconut coir, vermiculite, or perlite.

Conclusion

Peat-grown tomatoes were thought to be redder, softer, and more flavourful; the biggest variations in flavour appeared early in the harvest season. When compared to perlite, rice husk alone enhanced the sugar content of tomato fruit. Cucumber plant development was quicker and the yield was higher, when plants were grown in perlite or rockwool compared to coconut fibre (Böhme et al., 2001). Plants may more readily absorb nutrients because rockwool holds air and maintains nutrient solutions. If nutrient management is not at its best, the yield in organic medium may be lower than in inorganic media. Nutrient solution can be supplied many times per day to rockwool but fewer times to peat.

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