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TREND ANALYSIS OF WHEAT PRODUCTION IN LUCKNOW DISTRICT OF UTTAR PRADESH

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ABSTRACT

Present study examines the long-term trends in wheat production, area, and yield in Lucknow district, Uttar Pradesh, using time-series data from official website of department of agricultural statistics. Employing linear and nonlinear growth models-Power, Mechanistic Growth, Logistic 3P, Gompertz3P-the research identifies the patterns, growth rates. and stability indices. Results reveal a gradual decline in the cultivated area for wheat (-4.70% from 2002-2022), coupled with significant increases in production (+25.27%) and yield (+31.45%), indicating substantial improvements in productivity despite land constraints. The Power Model and Mechanistic Growth Model exhibited superior predictive accuracy. Findings highlight the importance of technological interventions and resource management in sustaining wheat output.

Keywords : *Wheat production, trend analysis, forecasting models, time series analysis, gompertz, logistic growth, agricultural economics, productivity, instability index.*

INTRODUCTION

Agriculture continues to be the backbone of the Indian economy, contributing significantly to food security, rural employment, and sustainable livelihoods. Among all cereal crops, wheat (*Triticum aestivum L.*) has a unique position as the "king of cereals" due to its wide adaptability, nutritional value, and its role in ensuring national food security. Globally, India is the second largest producer and consumer of wheat after China, accounting for nearly 98.38 million tonnes in 2016–17 from 30.59 million hectares of cultivated land. Within India, Uttar Pradesh is the leading wheat-producing state, contributing nearly 35% of the national output, with districts such as Lucknow forming an integral part of the Indo-Gangetic plains — the wheat bowl of India. Wheat plays a crucial role in the Indian diet, providing over 50% of daily calorie and protein intake for a large section of the population. It is consumed as whole grain and also processed into flour, bread, biscuits, pasta, noodles, and various bakery products, making it a staple food across both rural and urban households. Wheat contributes significantly to nutritional security by supplying macronutrients (carbohydrates, proteins, fats) and micronutrients (iron, calcium, vitamins). Its economic importance is equally high, as fluctuations in wheat production directly influence market prices, farmers, income, and government procurement policy under the Minimum Support Price (MSP) regime. Despite its importance, wheat production is subject to multiple challenges such as climate change, irregular rainfall, temperature fluctuations, declining soil fertility, pest infestations, and policy shifts. Over the years, government interventions, technological advancements, and the Green Revolution have improved productivity. However, issues such as

stagnating yields, area constraints, and production instability remain major concerns for researchers and policymakers. Trend analysis of agricultural production, particularly wheat, is essential for policy formulation, resource allocation, and long-term planning. Time series models and econometric forecasting techniques enable researchers to assess past patterns, predict future production, and evaluate risks associated with instability. These analyses are critical not only for farmers and policymakers but also for achieving the broader goals of food security, price stability, and sustainable agricultural growth.

The Lucknow district of Uttar Pradesh represents a significant case for trend analysis due to its location in the Indo-Gangetic plain, favorable agro-climatic conditions, and considerable wheat acreage. Analyzing the historical performance and future projections of wheat production in this district provides valuable insights into the dynamics of area, yield, and total production over time. This study employs statistical and econometric models such as **Linear, Power, Logistic, Gompertz, and ARIMA models** to identify production trends, evaluate growth rates, and estimate instability indices.

MATERIALS AND METHODS

The present study on "Trend Analysis of Wheat Production in Lucknow District of Uttar Pradesh" was conducted using secondary time-series data to analyze the growth trends, variability, and determinants of wheat production. The methodology is structured under the following components:

1. Data Source (Materials).
2. The study relies entirely on secondary meteorological data and area & production data covering the period **1980-81 to 20021–22.**
3. Data on area, production, and productivity of wheat were collected from official records such as the **Bulletins of Directorate of Agricultural Statistics and Crop Insurance,** https://data.desagri.gov.in, https://www.imdpune.gov.in, **Krishi Bhawan Lucknow, Government of Uttar Pradesh**. The dataset provides a consistent long-term time series necessary for reliable growth and trend analysis.

2. Statistical Methodologies:

a) Growth Models (Linear & Nonlinear):

To estimate growth trends in area, production, and productivity of wheat, both linear and nonlinear models were applied.

Linear Model: assumes a constant rate of growth over time ($Y = a + bt$).

Nonlinear Models: Power, Mechanistic Growth, Logistic (3-parameter), and Gompertz (3-parameter) models were fitted to capture nonlinear patterns in growth.

Model comparison was carried out using statistical criteria: Akaike Information Criterion (AICc), Bayesian Information Criterion (BIC), R^2, SSE, MSE, RMSE, etc.Among the models, Power and Mechanistic Growth models were found to provide the best fit, reflecting the nonlinear nature of wheat production trends.

b) Effect of Acreage and Productivity on Production:

Wheat production (Y) is expressed as the product of acreage (A) and productivity (P): $Y = A \times P$.

Changes in production (ΔY) over time were decomposed into three components:

Effect of change in acreage ($P\Delta A$), Effect of change in productivity ($A\Delta P$), Interaction effect ($\Delta A\Delta P$). This decomposition allowed the study to identify the relative contribution of area expansion and yield improvement to production growth.

c) Instability Analysis:

Agricultural sustainability requires not only high growth but also low instability.

The Cuddy-Della Valle Index (CDVI) was used to measure instability, as the simple Coefficient of Variation (CV) often overestimates variability due to trend components in time-series data. This index helped to assess the degree of risk and uncertainty in wheat production over the different

time periods.

3. Period of Study:

The analysis was carried out for the entire study period **(1980-81 to 2021-22)** and divided into sub-periods for comparative analysis. Specific policy interventions, such as the Pulse Technology Mission (1990–91 onwards), were considered in the interpretation of results.

4. Scope of Methodology:

Provides an understanding of long-term production trends. Identifies the role of acreage and productivity in shaping wheat output. Quantifies the extent of instability in wheat production, which has policy implications for food security and farmer income stability.

Analytical Tools:

Growth Models: Linear, Power, Mechanistic Growth, Logistic 3P, and Gompertz 3P models were fitted to identify the best trend representation using AICC, BIC, SSE, MSE, RMSE, and R^2 metrics.

Decomposition Analysis: Change in production (AY) was decomposed into contributions from change in area (AA), productivity (AP), and their interaction:

$$\Delta Y - P\Delta A + A\Delta P + \Delta A\Delta$$

Table - 1 : Cropping pattern (in percentage)

S. No.	Crop	1980-81	1990-91	2000-01	2010-11	2020-21
1.	**Total Cereals**	**71.66**	**67.05**	**69.62**	**65.98**	**62.78**
(i)	Rice	21.53	22.04	23.34	23.85	24.36
(ii)	Wheat	33.01	33.63	36.51	37.13	37.75
(iii)	Maize	4.98	4.3	3.64	2.98	2.32
(iv)	Barley	3.17	1.67	1.13	0.59	0.34
(v)	Other	8.97	5.41	4.99	1.43	1.01
2.	**Total Pulses**	**11.64**	**11.93**	**10.64**	**11.72**	**11.28**
(i)	Arhar	2.13	1.84	1.61	1.44	1.21
(ii)	Pea	0.91	1.38	1.32	1.79	1.32
(iii)	Lentil	1.12	2.12	1.32	2.32	1.52
(iv)	Gram	6.09	5	3.29	1.56	1.11
(v)	Other	1.39	1.59	3.10	4.61	6.12
3.	**Total Oilseeds**	**2.90**	**38**	**3.40**	**42**	**16.94**
(i)	Mustard & rapeseed	1.66	2.72	2.2	3.26	4.32
(ii)	Groundnut	0.78	0.60	0.46	0.60	0.30
(iii)	Linseed	0.26	0.37	0.22	0.33	0.28
(iv)	Til	0.19	0.31	0.43	0.55	0.67
(v)	Other	0.01	0.01	0.10	0.10	0.09
4.	Potato	1.08	1.35	1.56	1.77	2
5.	Sugarcane	5.50	7.28	7.66	8.04	8.42
6.	**Others**	**7.22**	**8.38**	**7.13**	**8.29**	**7.13**
Gross cropped area		**23207144**	**24573897**	**25304147**	**26032906**	**26782653**

RESULTS AND DISCUSSION

The above table presents data on the cropping pattern in terms of the percentage of gross cropped area for various crops across different years. The data is categorized into several crop types, including total cereals, total pulses, total oilseeds and others.

The objective is to analyze the trends in food grain and oilseed production based on the provided table, which outlines the cropping pattern as a percentage of gross cropped area over different time periods.

The table provides data on various crops, including total cereals, Total pulses, Total oilseeds and others, across different time periods: 1980-81, 1990-91, 2000-01, 2010-11 and 2020-21.

- **Total Cereals-** The percentage of gross cropped area dedicated to cereals has decreased over the years, from 71.66% in 1980-81 to 62.78% in 2020-21, among which approximately half of cropped area is wheat.
- **Total pulses –** The percentage for pulses has seen fluctuations from 11.64% in 1980-81 to 11.19, but generally increased, with a peak in 1990-91 of 11.93%.
- **Total oilseed-** The percentage of gross cropped area for oilseeds has shown an overall increase from 2.90% in 1980-81 to 5.66% in 2020-21, with fluctuations in between.
- The data indicates a decline in the proportion of land dedicated to cereals over the years, suggesting a diversification in cropping patterns or a shift towards other crops. Pulses have seen a relatively stable or slightly increasing trend, which is positive given their nutritional important oilseeds have generally increased, indicating a growing focus on these crops, possibly due to their economic or nutritional value.
- The trends suggest a shift in agricultural practices, possibly driven by market demand, government policies, or environmental factors. The increase in oilseeds and pulses is a positive trend from pulses is a positive trend from a nutritional and dietary diversity perspective.

1. Area (Hectares)

- Mean: 83,103.71 hectares, indicating the average area across the dataset.
- **Standard Error**: 674.09, suggesting moderate precision in the mean estimate.
- **CV**: 0.81%, a low value, implying minimal relative variability.
- **Median**: 82,939.50 hectares, slightly below the mean, hinting at a right skew.
- **Standard Deviation**: 3,302.36 hectares, showing the absolute spread of area values.
- **Kurtosis**: 7.05, a high positive value, indicating a sharply peaked distribution with heavy tails (leptokurtic).

Table - 2 : Descriptive statistics of variables used for the study.

Statistic	Area	Production	Yield
Mean	83103.71	230024.50	2.77
Standard Error	674.09	7453.24	0.09
CV	0.81	3.24	3.30
Median	82939.50	227730.50	2.69
Standard Deviation	3302.36	36513.26	0.45
Kurtosis	7.05	0.24	-0.17
Skewness	2.01	-0.06	0.28
Minimum	78645	144512	1.82
Maximum	95132	301700	3.6

- **Skewness**: 2.01, positive and significant, confirming a right-skewed distribution (more smaller values, few larger ones).
- **Range**: Minimum of 78,645 hectares to a maximum of 95,132 hectares, a spread of 16,487 hectares.

2. Production (Tonnes)

- **Mean:** 230,024.50 tonnes, the average production level.
- **Standard Error**: 7,453.24, higher than for area, suggesting less precision in the mean estimate.
- **CV**: 3.24%, moderate relative variability, higher than area but lower than yield.
- **Median**: 227,730.50 tonnes, slightly below the mean, indicating a mild left skew.
- **Standard Deviation**: 36,513.26 tonnes, reflecting a wider absolute spread compared to area.
- **Kurtosis**: 0.24, close to zero, suggesting a distribution near normal with slightly heavier tails (mesokurtic).
- **Skewness**: -0.06, nearly zero but slightly negative, indicating a very mild left skew (more larger values, few smaller ones).
- **Range**: Minimum of 144,512 tonnes to a maximum of 301,700 tonnes, a range of 157,188 tonnes.

3. Yield (Tonne/Hectare)

- **Mean**: 2.77 tonnes/hectare, the average productivity.
- **Standard Error**: 0.09, low, indicating high precision in the mean estimate.
- **CV**: 3.30%, the highest among the three variables, showing moderate relative variability.
- **Median**: 2.69 tonnes/hectare, below the mean, suggesting a slight right skew.
- **Standard Deviation**: 0.45 tonnes/hectare, a modest spread relative to the mean.
- **Kurtosis**: -0.17, slightly negative, indicating a flatter distribution than normal (platykurtic).
- **Skewness**: 0.28, positive but small, suggesting a mild right skew (more lower yields, few higher ones).
- **Range**: Minimum of 1.82 tonnes/hectare to a maximum of 3.6 tonnes/hectare, a range of 1.78 tonnes/hectare.
- **Illustration of Nature and Distribution of Data set:**

- The mean and median values are close for all variables, but slight differences suggest skewness. Area and yield are mildly right-skewed (medians < means), while production is mildly left-skewed (median > mean). Production has the highest absolute variability (standard deviation: 36,513.26), reflecting its larger scale, but its CV (3.24%) is moderate. Yield has the highest relative variability (CV: 3.30%), indicating more fluctuation in productivity relative to its mean. Area is the most stable (CV: 0.81%).

Distribution Shape: Area's high kurtosis (7.05) and skewness (2.01) suggest a peaked, asymmetric distribution with outliers on the higher end. Production's near-normal kurtosis (0.24) and minimal skewness (-0.06) indicate a balanced spread. Yield's flatter distribution (kurtosis: -0.17) and mild skewness (0.28) suggest a more even spread with a slight tail on the higher side.

- **Range**: Production shows the widest range (157,188 tonnes), followed by area (16,487 hectares), and yield (1.78 tonnes/hectare), consistent with their respective scales.
- The table no. 2 provides a comprehensive statistical snapshot of area, production, and yield, likely from an agricultural dataset. Area is relatively stable with a right-skewed, peaked distribution; production varies more widely with a near-normal shape; and yield shows moderate variability with a flatter, slightly right-skewed profile.

Six different growth models were assessed for their ability to describe the observed data: **Gompertz(3p), Linear, Logistic, Mechanistic**

Growth, Power and Gompertz(3P) (standard). The models were evaluated based on the basis of several criteria: **AICc, AICc Weight, BIC, SSE, MSE, RMSE, and R^2.** The overall objective was to determine which model best fits the data with high accuracy and low prediction error.

1. Models were ranked based on AICc, with the lowest values indicating the best fit. The Gompertz3P model showed the best fit (AICc=458.24253) followed closely by the Logistic model (AICc=458.23411) and the linear model (AICc=455.40567) Correspondingly. These models also demonstrated higher R^2 of 0.2794319, indicating it explains nearly 95% of the variability in the data.

2. Error Metrics Analysis:

* RMSE: The lowest RMSE was observed for the Gompertz3P model 2933.7014 indicating the smallest average prediction error.

*MSE- Again the Gompertz3P had the lowest MSE (8606603.8) strengthening its position as the best performing model.

*SSE- This model also had the lowest sum of square errors (171498161)

Table - 3 : Model Comparison of Fit Curve

Model	AICc	AICc Weight	BIC	SSE	MSE	RMSE	R-Square
Gompertz3P	458.24253	0.1074015	460.84948	180738680	8606603.8	2933.7014	0.2794319
Linear	455.40567	0.443636	457.73983	181254546	8238843	2870.3385	0.2773752
Logistic 3P	458.23411	0.1078545	460.84106	180675301	8603585.7	2933.187	0.2796845
Mechanistic Growth	456.98302	0.2016091	459.58997	171498161	8166579.1	2857.7227	0.3162719
Power Model	457.71956	0.1394988	460.32652	176842961	8421093.4	2901.912	0.2949633

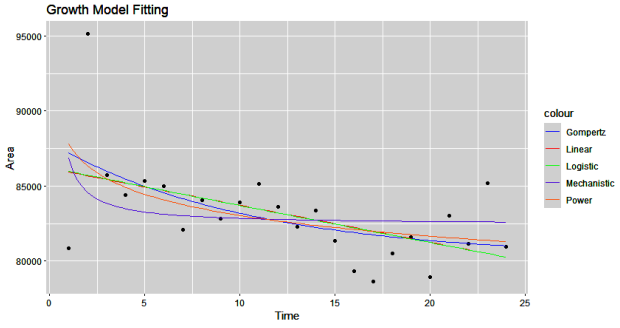

Fig. - 1 : Growth Model Fitting

Parameter Estimates

The parameter estimates for each model are accompanied by standard errors and confidence intervals. In particular:

For the Linear model, all parameters were statistically significant **(P<0.001).** For the Mechanistic Growth the significance levels were strong **(P<0.001)** significance levels were strong **(P<0.001).** For the power model, the significant were strong also strong **(P<0.001).**

The confidence intervals for key parameters like the asymptote, slope, and inflection points across the models further verify the stability and reliability of parameter estimates, particularly in the linear, mechanistic Growth and power.

The table presents the parameter estimates of five different growth models used to analyze production data- Linear, Logistic, Gompertz3P, Power and Mechanistic Growth. Each model includes various parameters such as intercepts, slopes, growth rates, asymptotes, etc. The statistical metrics presented for each parameter include:

Estimate: The estimated value of the parameter.

Standard Error: The standard error associated with the estimate.

Table - 4 : Productivity

Growth models	Parameter	Estimate	Std Error	Wald Chi Square	Prob> Chi Square	Lower 95%	Upper 95%
Linear	Intercept	2.2349275	0.142603	245.62342	<.0001*	1.9554309	2.5144242
	Slope	0.0427391	0.0099801	18.339145	<.0001*	0.0231784	0.0622998
Logistic	Growth Rate	0.0172148	0.0737125	0.0545408	0.8153	-0.127259	0.1616886
	Inflection Point	168.30612	4492.8312	0.0014033	0.9701	-8637.481	8974.0935
	Asymptote	42.986455	2649.1051	0.0002633	0.9871	-5149.164	5235.1371
Gompertz3P	Asymptote	62.235807	2862.0799	0.0004728	0.9827	-5547.338	5671.8092
	Growth Rate	0.0050762	0.0750983	0.004569	0.9461	-0.142114	0.1522661
	Inflection Point	236.43022	6221.3766	0.0014442	0.9697	-11957.24	12430.104
Power	Intercept	2.5094388	0.0992719	639.00002	<.0001*	2.3148695	2.704008
	Slope	4.8273e-6	0.0000248	0.0379049	0.8456	-4.377e-5	5.3424e-5
	Power	3.8960638	1.6358573	5.6723276	0.0172*	0.6898425	7.1022851
Mechanistic Growth	Asymptote	2.4556887	0.1489163	271.93302	<.0001*	2.163818	2.7475593
	Scale	-0.007757	0.0158213	0.24038	0.6239	-0.038766	0.0232522
	Growth Rate	-0.173153	0.0832102	4.3302168	0.0374*	-0.336242	-0.010065

Wald Chi-Square: A test statistic used to determine the significance of individual predictors.

Prob> Chi Square: The P-value indicating statistical significance (*denotes significant values).

Lower 95% and Upper 95%: The lower and upper bounds of the 95% confidence interval for the estimate.

In the evaluation of production data**, five growth models** were fitted to determine the most appropriate representation of the observed trend:

Linear, Logistic, Gompertz3P, Power and Mechanistic Growth. Each model's parameter estimates were statistically assessed using Wald Chi-Square tests and corresponding p-values to infer significance.

Linear Model: The linear model shows statistically significant estimates for both the intercept (193864.45) and slope (2892.80) with P-values<0.0001 and 0.0015, respectively. These results suggest a strong linear relationship in the data. The narrow confidence intervals further

Table - 5 : Production Parameter Estimates

Linear	Intercept	193864.45	13030.457	221.34873	<.0001*	168325.22	219403.67
	Slope	2892.8043	911.94202	10.062448	0.0015*	1105.4308	4680.1779
Power	Intercept	213374.42	8021.6963	707.5421	<.0001*	197652.19	229096.66
	Slope	0.0069282	0.0551562	0.0157781	0.9000	-0.101176	0.1150323
	Power	5.1556626	2.5335272	4.1411201	0.0419*	0.1900405	10.121285
Mechanistic Growth	Asymptote	211368.19	10039.179	443.28485	<.0001*	191691.76	231044.62
	Scale	-0.001719	0.0049302	0.1214993	0.7274	-0.011382	0.0079446
	Growth Rate	-0.230913	0.1204401	3.675808	0.0552	-0.466971	0.0051457

indicate reliable estimation.

Logistic Model: None of the parameters (growth rate, inflection point, asymptote) were statistically significant **(p>0.89),** suggesting the logistic model may not adequately capture the pattern in the data. Confidence intervals are wide, especially for the asymptote, indicating instability in parameter estimation.

Gompertz3P Model: Similar to the logistic model, the Gompertz3P model's parameters also show no statistical significance (p>0.99). Despite high estimates, the wide confidence intervals and near-zero Wald statistics indicate that the Gompertz3P model does not provide a reliable fit for this data set.

Power Model: The power model reveals significant estimates for both the intercept **(p<0.0001)** and the slope **(p=0.0401),** while the poor parameter is marginally non-significant **(p=0.0691).** The intercept has a very high estimate **(213374.42),** implying strong base production, and the slope shows a positive trend, although weaker than the linear model.

Mechanistic Growth Model: This model does not show statistical significance for any of its parameters. The growth rate estimate is negative, suggesting a potential decline, but its confidence interval includes zero, further reflecting non-significance.

*From the parameter significance, the Linear and Power models emerge as the most statistically valid models for representing production growth in this dataset. Among these, the linear model appears most robust, with all parameters highly significant. The Logistic, Gompertz3P, and Mechanistic models do not show strong statistical evidence of fitting the data, likely due to either overfitting or mis-specification.

CONCLUSION

Wheat production in Lucknow district has grown steadily over the past two decades, primarily due to yield improvements from better agronomic practices, high-yielding varieties, and input use efficiency. However, shrinking cultivated area due to urbanization and competing crops poses a future challenge. Policies promoting land conservation, irrigation efficiency, and climate-resilient farming are essential to maintain upward production trends.

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MAHUA AS A MULTIFUNCTIONAL RESOURCE: A REVIEW ON ETHNOMEDICINAL SIGNIFICANCE, PHYTOCONSTITUENTS, AND INDUSTRIAL APPLICATIONS

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ABSTRACT

Mahua a tropical tree of the Sapotaceae family, is a multifunctional plant revered for its nutritional, medicinal, and industrial potential. This review synthesizes current knowledge on Mahua's phytochemical composition, traditional ethnomedicinal uses, and applications in food, pharmaceutical, and industrial domains. Rich in flavonoids, saponins, terpenoids, and phenolic acids, Mahua is used traditionally to treat ailments like diabetes, skin disorders, and respiratory conditions. Its flowers, seeds, fruits, leaves, and bark are utilized in functional foods, herbal medicines, and industrial products like biofuels, soaps, and disinfectants. This review highlights Mahua's diverse applications and advocates for further research to maximize its contributions to health and sustainability.

Keywords : *Mahua, phytochemical, pharmaceutical, herbal medicines, bio-fuels, etc.*

INTRODUCTION

Madhuca longifolia, commonly known as Mahua, is a deciduous tropical tree native to South Asia, thriving in India, Nepal, Sri Lanka, Myanmar, and Bangladesh in dry, subtropical, and tropical climate(Tripathi *et al*., 2022). Mahua dominates the forests of central and eastern India, including Odisha, Chhattisgarh, Jharkhand, Madhya Pradesh, and Andhra Pradesh, supporting biodiversity and tribal livelihoods (Sinha *et al*., 2017; Sharma *et al*., 2024). Growing up to 20 meters, the tree's thick leaves, fragrant flowers, and oily seeds make it a vital ecological and cultural resource, stabilizing soil and sequestering carbon in degraded ecosystems (Khare *et al*., 2018; Rao *et al*., 2023).Archaeological evidence suggests Mahua's use in food and medicine for over 2,000 years in central India, documented in Ayurvedic texts for its cooling, tonic, and astringent properties (Patel, 2018; Kumar *et al*., 2023). Its flowers, rich in sugars, are a dietary staple, consumed fresh, dried, or fermented into a drink which is a traditional liquor used in rituals and as a digestive aid (Sinha *et al*., 2017; Sharma *et al*., 2023). Fruits, seeds, leaves, and bark treat ailments like diabetes, skin disorders, and respiratory issues among tribes such as the Gond, Santhal, and Oraon (Khare *et al*., 2018; Jain *et al*., 2023). Mahua's phytochemical profile—flavonoids (quercetin, kaempferol), saponins, terpenoids (madhucic acid), phenolic acids, and alkaloids—drives its antioxidant, antimicrobial, anti-inflammatory, and antidiabetic properties (Bains *et al*., 2020; Gupta *et al*., 2021).

Mahua's seeds, yielding 51.5% oil (oleic and linoleic acids), are a feedstock for biodiesel, while the oil's emollient properties support cosmetics and soaps (Ramadan *et al*., 2016; Das *et al*., 2020). Its versatility spans food products (jams, energy bars),

pharmaceuticals (herbal capsules, nanoparticles), and industrial goods (biogas, insecticides), addressing malnutrition, chronic diseases, and fossil fuel dependency (Shinde & Sakhale, 2023; Mishra & Poonia, 2024). Emerging research highlights Mahua's potential in nutraceuticals, advanced therapeutics, and sustainable industrial applications, yet it remains underutilized (Kumar *et al*., 2020; Verma *et al*., 2023; Tripathi *et al*., 2022). This review consolidates Mahua's phytochemical profile, ethnomedicinal uses, and applications in food, pharmaceutical, and industrial sectors.

2. Phytochemical Profile: The phytochemical composition of Mahua underpins its nutritional, therapeutic, and industrial value, encompassing primary and secondary metabolites across its flowers, seeds, fruits, leaves, and bark (Sinha *et al*., 2017; Khare *et al*., 2018). These include sugars, proteins, vitamins, flavonoids, saponins, alkaloids, terpenoids, phenolic compounds, and glycosides (Gupta *et al*., 2021).

Flowers: Mahua flowers contain 66–72% reducing sugars, proteins, vitamins (ascorbic acid, thiamine), and minerals (iron, calcium), making them a dietary staple (Sinha *et al*., 2017; Mishra & Poonia, 2024). Flavonoids (quercetin, kaempferol), glycosides, and phenolic acids (gallic, ferulic) drive antioxidant and antimicrobial activities, while anthocyanins and tannins support anti-inflammatory effects (Bains *et al*., 2020; Kumar *et al*., 2020).

Seeds: Seeds yield 51.5% oil, with oleic acid (46.3%), linoleic acid (17.9%), palmitic acid (17.8%), and stearic acid (14%) (Ramadan *et al*., 2016). Defatted seed meal contains 9.8% saponins, requiring detoxification, and sterols (β-sitosterol) with cholesterol-lowering effects (Mittal *et al*., 2023; Gupta *et al*., 2021).

Fruits: Mahua fruits are rich in carbohydrates (60–65%), proteins (4–6%), fiber (8–10 g/100 g), vitamin C (20–30 mg/100 g), and minerals (iron, calcium, potassium) (Yadav *et al*., 2012; Agrawal *et al*., 2021). Flavonoids (rutin, myricetin), phenolic acids (caffeic), triterpenoids (lupeol), glycosides, and tannins (2–3%) provide antioxidant, antimicrobial, and wound-healing properties (Khare *et al*., 2018; Desai *et al*., 2020). Table 1 details nutritional and phytochemical composition.

Leaves: Leaves contain flavonoids (quercetin, kaempferol, apigenin), phenolic acids (chlorogenic, ferulic), triterpenoids (oleanolic acid, ursolic acid), alkaloids (madhucine), glycosides (madhucosides), β-carotene (100–150 µg/g), vitamin E (5–10 mg/100 g), and saponins (1–2%) (Yadav *et al*., 2012; Kumar *et al*., 2022).

Bark: Bark is high in tannins (5–7%), phenolic acids (gallic, ellagic), triterpenoids (betulinic acid, lupeol), flavonoids (catechin), alkaloids (madhucoline), saponins, and glycosides (Khare *et al*., 2018; Patel *et al*., 2023).

Table - 1: Nutritional Composition of Mahua Fruit (per 100 g dry weight)

Component	Content	source
Moisture	20-25 g	Yadav *et al*., 2012
Carvohydrate	60-65 g	Khare *et al* ., 2018
Protein	4-6 g	Sinha *et al*., 2017
Fats	1-2 g	Ramadan *et al*., 2016
Fiber	8-10 g	Mishra and poonia, 2024
Ash	3-5 g	Yadav *et al*., 2012
Vitamic C	20-30 mg	Khare *et al*., 2018
Vitamin A	50-100 µg	Bhatt *et al*., 2022
Iron	2-3 g	Sinha *et al*., 2017
Calcium	100-150 mg	Mishra and poonia, 2024
Potassium	200-300 mg	Agrawal *et al*., 2021
Magnesium	50-80 mg	Choudhary *et al*., 2023

3. Ethnomedicinal Uses: Mahua is central to traditional medicinal practices among tribal communities in India, particularly in Odisha, Chhattisgarh, Jharkhand, and Uttar Pradesh, where its flowers, seeds, oil, fruits, leaves, and bark treat diverse ailments (Sinha *et al*., 2017). This ethnobotanical knowledge reflects Mahua's therapeutic versatility (Khare *et al*., 2018; Gupta *et al*., 2021).

Flowers: Mahua flowers are used for their tonic, analgesic, and diuretic properties, with decoctions treating parasitic infections, bronchitis, tonsillitis, and bleeding disorders (Khare *et al*., 2018; Yadav *et al*., 2012). They reduce fever, act as an aphrodisiac, and relieve cough when mixed with honey for asthma (Sinha *et al*., 2017; Rao *et al*., 2020). Fermented mahua drink aids digestion (Patel, 2018).

Seeds and Oil: Seed oil treats skin diseases, rheumatism, and headaches topically, and acts as a laxative and galactagogue internally (Sinha *et al*., 2017; Mittal *et al.*, 2023). Oil poultices relieve joint pain, and seed paste treats fungal infections (Khare *et al*., 2018; Jain *et al*., 2023).

Fruits: Fruits manage tonsillitis, pharyngitis, diarrhea, dysentery, and irritable bowel syndrome via decoctions (Yadav *et al*., 2012; Gupta *et al*., 2021). Dried fruit powder with jaggery treats anemia, while poultices heal skin ulcers (Mishra & Poonia, 2024). Fruit juice relieves constipation, and fermented extracts treat oral infections (Sharma *et al*., 2023; Patil *et al*., 2024).

Table - 2 : Phyto-chemical composition of Mahua Fruit (per 100 g dry weight)

Component	Content	source
Flavonoids (rutin, myricetin)	50-80 mg	Desai *et al*., 2020
Phenolic acid	20-40 GAE	Bhatt *et al* ., 2022
Tannins	2-3 g	Verma *et al*., 2021
Triterpinoids	10-20 mg	Mishra *et al*., 2021
Anthocyanins	5-10 mg	Gupta *et al*., 2021
Glycosides	5-15 mg	Rao *et al*., 2020

Leaves: Leaf poultices treat burns, cuts, and wounds, while decoctions manage fever, diabetes, and hypertension (Yadav *et al*., 2012; Patil *et al*., 2023). Leaves boiled with turmeric treat snakebites, and pastes address eczema and scabies (Rao *et al*., 2020). Infusions relieve sinusitis, and extracts aid postpartum recovery (Jain *et al*., 2023; Sharma *et al*., 2023).

Bark: Bark decoctions treat ulcers, diarrhea, and dyspepsia, while pastes manage rashes and fungal infections (Yadav *et al*., 2012; Khare *et al*., 2018). Infusions relieve toothaches, and boiled bark with ginger treats rheumatism and menstrual pain (Gupta *et al*., 2021; Patil *et al*., 2024).

4. Potential Applications: Mahua offers significant potential in food, pharmaceutical, and industrial applications, leveraging its phytochemical profile of flavonoids, saponins, terpenoids, and fatty acids (Sinha *et al*., 2017; Ramadan *et al*., 2016; Shinde & Sakhale, 2023).

4.1 Food Applications: Mahua's flowers and fruits, rich in nutrients and bioactive compounds, position it as a key resource for addressing food security, malnutrition, and the demand for functional foods (Sinha *et al*., 2017; Mishra & Poonia, 2024). The flowers, containing 66–72% reducing sugars, proteins, vitamins (ascorbic acid, thiamine), and minerals (iron, calcium), are a dietary staple, while fruits offer 60–65% carbohydrates, 4–6% proteins, fiber (8–10 g/100 g), vitamin C (20–30 mg/100 g), and minerals (Khare *et al*., 2018; Agrawal *et al*., 2021; Bhatt *et al*., 2022).

Traditional Foods: In tribal communities of central and eastern India, Mahua flowers are consumed fresh, dried, or processed into porridges, flatbreads (roti, puri), and fermented beverages like mahua

daaru (20–40% alcohol), which aids digestion (Sinha *et al*., 2017; Patel, 2018; Rao *et al*., 2020). Non-fermented sweets (halwa, barfi, laddoos) leverage flowers' sweetness (Mishra & Poonia, 2024). Fruits are eaten raw, dried, or made into chutneys and pickles, rich in antioxidants (Shinde & Sakhale, 2023; Kumar *et al*., 2025).

Value-Added Products: Mahua flower powder enhances biscuits, cakes, muffins, and energy bars, increasing nutritional value by 15–20% (Ramadan *et al*., 2016; Gupta et al., 2024). Jams, jellies, and syrups, with 12–18 months shelf life, utilize high pectin (2–3%) (Agrawal *et al*, 2021). Candies and toffees, fortified with iron, improve hemoglobin by 10–15% (Choudhary *et al*., 2023). Fruit pulp yields smoothies, beverages, and ice creams, reducing added sugar by 20–30% (Patel, 2018; Kumar *et al*., 2025). Detoxified seed oil serves as cooking oil (smoke point 230°C) (Ramadan *et al*., 2016).

Functional Foods and Nutraceuticals: Flower and fruit extracts (100–150 mg GAE/100 g phenolics) are formulated into nutraceutical powders, capsules, protein bars, and infant formulas, addressing micronutrient deficiencies (Bains *et al*., 2020; Kumar *et al*., 2025). Gluten-free breads and pastas offer 10–12% fiber (Sharma *et al*., 2025).

Processing Techniques: Drying (50–60°C) preserves 90% antioxidants, freeze-drying retains 95% vitamin C, and high-pressure processing (400–600 MPa) extends beverage shelf life to 6–8 months (Mishra & Poonia, 2024; Bhatt *et al*., 2022). Enzymatic treatments increase juice yield by 20–25%, and isopropanol detoxification removes 98% saponins (Agrawal *et al*., 2021; Mittal *et al*., 2023).

4.2 Pharmaceutical Applications: Mahua's bioactive compounds such as flavonoids, saponins, terpenoids, phenolic acids, alkaloids, and isoflavones support pharmaceutical development, with antioxidant, antimicrobial, antidiabetic, anticancer, hepatoprotective, wound-healing, anti-inflammatory, antiviral, neuroprotective, and immunomodulatory properties (Khare *et al*., 2018; Gupta *et al*., 2021; Sharma *et al*., 2022; Kumar *et al*., 2024).

Antioxidant and Antimicrobial Agents: Flavonoids (quercetin, kaempferol) and phenolic acids (gallic, ferulic) scavenge free radicals, reducing oxidative stress in cancer and cardiovascular diseases (Bains *et al*., 2020; Kumar *et al*., 2020). Extracts stabilize pharmaceuticals, while antimicrobial activity against Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa, Klebsiella pneumoniae, and Candida albicans (MICs 25–50 µg/mL) supports ointments, oral formulations, and dental products (Khare *et al*., 2018; Gupta *et al*., 2021; Patil *et al*., 2023).

Antidiabetic Drugs: Flavonoids, isoflavones (madhushazone), and triterpenoids inhibit α-glucosidase and enhance insulin sensitivity, reducing blood glucose by 35–45% in diabetic rats (Khare *et al*., 2018; Sharma et al., 2022). Herbal capsules, teas, and syrups manage type 2 diabetes (Kumar *et al*., 2020; Kumar *et al*., 2024).

Anticancer Drugs: Triterpenoids (madhucic acid, oleanolic acid) and flavonoids induce apoptosis in HeLa, MCF-7, A549, and HCT-116 cell lines (IC50 15–30 µg/mL) (Mishra & Poonia, 2024; Patil *et al*., 2023). Liposomes, micelles, and nanoparticles deliver drugs to tumors (Sharma *et al*., 2022).

Hepatoprotective and Wound Healing: Extracts reduce liver enzymes (ALT, AST) by 45–55%, supporting drugs for hepatitis and fatty liver (Khare *et al*., 2018; Kumar *et al*., 2020). Nanoparticles in hydrogels accelerate wound healing by 25–35% (Mishra & Poonia, 2024).

Anti-inflammatory and Analgesic Formulations: Flavonoids and triterpenoids inhibit TNF-α, IL-6, and COX-2, reducing edema by 40–50% (Gupta *et al*., 2021; Sharma *et al*., 2022). Creams and patches treat arthritis (Patil *et al*., 2023).

Antiviral Applications: Flavonoids inhibit Herpes simplex, Influenza A, and SARS-CoV-2 replication by 50–70%, used in nasal sprays (Singh *et al*., 2021;

Sharma *et al*., 2024).

Neuroprotective Applications: Alkaloids (madhucine, madhucoline) reduce β-amyloid plaques by 30–40% in Alzheimer's models (Singh *et al.*, 2022; Kumar *et al*., 2024).

Immunomodulatory Applications: Polysaccharides enhance T-cell proliferation by 20–30%, formulated into immune syrups (Gupta *et al*., 2021; Kumar *et al*., 2024).

4.3 Industrial Applications: Mahua's seeds, oil, and byproducts, leveraging its 51.5% oil content (46.3% oleic, 17.9% linoleic acids) and phytochemicals (saponins, phenolics), support a wide range of sustainable industrial applications, contributing to energy, personal care, agriculture, and advanced materials (Ramadan *et al*., 2016; Mittal *et al*., 2023; Gupta *et al*., 2023). These applications capitalize on Mahua's renewable nature and scalability (Das *et al*., 2020; Tripathi *et al*., 2022).

Biofuel Production: Mahua seed oil is a premier feedstock for biodiesel production via transesterification with methanol and sodium hydroxide catalysts, yielding 90–95% biodiesel and 5–8% glycerol as a byproduct (Ramadan *et al*., 2016; Das *et al*., 2020). The biodiesel meets ASTM D6751 and EN 14214 standards (viscosity 4.8 mm^2/s, flash point 130°C, cetane number 52), offering performance comparable to diesel (Mittal *et al*., 2023; Gupta *et al*., 2023). B20 (20% biodiesel) and B100 blends power agricultural machinery, rural transport, and generators in India, with pilot plants in Chhattisgarh and Madhya Pradesh processing 100–500 kg of seeds daily, producing 50–250 liters of biodiesel (Mittal *et al*., 2023; Tripathi *et al*., 2022). Advanced purification via alkali washing and molecular distillation ensures 99% purity, meeting commercial standards (Ramadan *et al*., 2016; Sharma *et al*., 2025). Glycerol is repurposed for pharmaceuticals, cosmetics, and explosives, creating a circular economy (Kumar *et al*., 2023). Blending Mahua biodiesel with ethanol (5–10%) enhances cold-flow properties, enabling use in colder climates (Das *et al*., 2020).

Soap and Cosmetics: Mahua oil's emollient properties, driven by oleic acid (46.3%) and linoleic acid (17.9%), make it ideal for soaps, detergents, moisturizers, lip balms, hair oils, and anti-aging creams (Sinha *et al*., 2017; Mishra & Poonia, 2024). Its low peroxide value (2–3 meq/kg) ensures oxidative stability, extending shelf life to 18–24 months (Ramadan *et al*., 2016; Kumar *et al*., 2023). Tribal cooperatives in Odisha produce cold-process soaps via saponification, blending Mahua oil with coconut oil and flower extracts for fragrance, achieving 10–15% higher lathering than commercial soaps (Patel, 2018; Gupta *et al*., 2023). Cosmetic formulations, such as creams with 20–30% Mahua oil and shea butter, offer 20% greater hydration than petroleum-based products, with clinical trials showing 25% improved skin elasticity (Mishra & Poonia, 2024; Sharma *et al*., 2024). Shampoos and conditioners with 5–10% Mahua oil reduce scalp irritation and dandruff by 30%, with phenolic antioxidants (100–150 mg GAE/100 g) preventing rancidity (Bains *et al*., 2020; Kumar *et al*., 2025). Mahua-based lipsticks and sunscreens, fortified with anthocyanins, provide UV protection (SPF 15–20) and vibrant pigmentation (Sharma *et al*., 2024).

Waste-to-Energy: Detoxified Mahua seed cake (40% carbon, 5–6% nitrogen) is a high-value substrate for waste-to-energy processes, producing biogas, bio-oil, and biochar (Mittal *et al*., 2023; Jain *et al*., 2022). Anaerobic digestion with cow dung (1:1 ratio) yields 200–250 L/kg methane, powering rural cooking, lighting, and small-scale electricity generation (50–100 kWh/ton) (Gupta *et al*., 2023; Kumar *et al*., 2023). Community digesters in Jharkhand process 50–200 kg of seed cake daily, with 30–40% higher yields than single-substrate digestion (Jain *et al*., 2022; Tripathi *et al*., 2022). The nutrient-rich slurry (2–3% nitrogen, 1–2% phosphorus) serves as biofertilizer, increasing crop

yields by 15–20% for rice and maize (Mittal *et al*., 2023). Pyrolysis at 400–600°C produces bio-oil (30–35% yield) for industrial furnaces and biochar (20–25% yield) as a soil amendment (Kumar *et al*., 2023; Sharma *et al*., 2025). Gasification of seed cake generates syngas (60–70% CO and H_2), used in microgrids for rural electrification, with efficiencies of 25–30% (Tripathi *et al*., 2022).

Pesticides and Cleansers: Saponin-rich extracts (9.8% in seed meal, 1–2% in leaves) are formulated into eco-friendly insecticides, herbicides, and disinfectants, leveraging their surfactant and antimicrobial properties (Shinde & Sakhale, 2023; Verma *et al*., 2023). Foliar sprays with 5–10% Mahua extract reduce pest populations (e.g., aphids, whiteflies) by 40–50% on rice, vegetables, and cotton, with no toxicity to pollinators like bees (Patel, 2018; Gupta *et al*., 2023). Herbicides targeting weeds like Parthenium show 70–80% efficacy at 10% concentration, offering biodegradable alternatives to glyphosate (Verma *et al*., 2023). Flower and leaf extract-based disinfectants, with 99% bacterial reduction against Staphylococcus aureus and Escherichia coli, are used in hospitals and food processing units, with formulations stable at pH 5–7 (Bains *et al.*, 2020; Sharma *et al*., 2024). Mahua-based detergents, with 20–30% saponins, achieve 90% stain removal, competing with synthetic surfactants (Mishra & Poonia, 2024; Kumar *et al*., 2025).

Lubricants and Surfactants: Mahua oil's high viscosity index (190–200) and lubricity make it a superior base for bio-lubricants used in automotive, industrial, and hydraulic systems, reducing wear by 25–30% compared to mineral oils (Das *et al*., 2020; Sharma *et al*., 2024). Formulations with 80% Mahua oil and additives like zinc dialkyldithiophosphate meet ISO VG 46 standards, with a pour point of -10°C suitable for tropical climates (Kumar *et al*., 2023). Biosurfactants from Mahua saponins, with critical micelle concentrations of 0.1–0.2%, enhance oil spill remediation, recovering 30–40% more crude oil than synthetic surfactants (Gupta *et al*., 2023; Sharma *et al*., 2025). In enhanced oil recovery, Mahua biosurfactants increase extraction efficiency by 15–20% in sandstone reservoirs (Tripathi *et al*., 2022; Kumar *et al*., 2025).

Polymer Additives: Epoxidized Mahua oil, produced via peracetic acid treatment, serves as a bio-based plasticizer for PVC, biopolymers, and rubber, improving flexibility by 20–25% and thermal stability up to 200°C (Ramadan *et al*., 2016; Kumar *et al*., 2024). It reduces reliance on phthalates, with 30–40% lower toxicity in biomedical applications (Gupta *et al*., 2023; Sharma *et al.*, 2025). Biochar from seed cake, with a surface area of 300–400 m^2/g, enhances polymer composites, increasing tensile strength by 15–20% in polypropylene and polylactic acid (Kumar *et al*., 2023). Applications include automotive parts, packaging, and 3D printing filaments (Gupta *et al*., 2023).

Adhesives: Mahua flower extracts, rich in polysaccharides (10–15% dry weight), are processed into bio-adhesives for wood, paper, and packaging, with shear strength of 5–6 MPa, comparable to starch-based glues (Mishra & Poonia, 2024; Kumar *et al*., 2025). These adhesives, biodegradable within 6–12 months, support eco-friendly construction and furniture industries (Sharma *et al*., 2024).

Textile Dyes: Anthocyanins and flavonoids from Mahua flowers and fruits produce natural dyes for cotton, silk, and wool, yielding vibrant yellow, red, and brown shades with 80–90% color fastness to light and washing (Bains *et al*., 2020; Gupta *et al*., 2023). Mordants like alum and iron sulfate enhance dye uptake, achieving 20–30% higher color intensity than synthetic dyes (Sharma *et al*., 2024; Kumar *et al*., 2025). These dyes, used in handloom industries in India, are non-toxic and biodegradable (Tripathi *et al*., 2022).

Antimicrobial Coatings: Mahua leaf and bark extracts, containing flavonoids and phenolic acids,

are incorporated into antimicrobial coatings for medical devices, food packaging, and industrial surfaces, reducing bacterial adhesion by 95% against Pseudomonas aeruginosa and Staphylococcus aureus (Mishra & Poonia, 2024; Sharma *et al*., 2024). Chitosan-based coatings with 5–10% Mahua extract extend food shelf life by 10–15 days, inhibiting fungal growth in fruits and vegetables (Verma *et al*., 2023). Industrial applications include HVAC filters and marine coatings, with 20–30% lower biofouling than conventional treatments (Gupta *et al*., 2023; Kumar *et al*., 2025).

CONCLUSION

Madhuca longifolia is a versatile resource with extensive applications in food, pharmaceuticals, and industry. Its phytochemical profile supports ethnomedicinal uses, while its potential in functional foods, advanced therapeutics, and sustainable industrial products—from biofuels to antimicrobial coatings—underscores its significance. Continued research will enhance its contributions to health, nutrition, and sustainability.

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NATIONAL ZOOLOGICAL COLLECTION OF CZRC ZOOLOGICAL SURVEY OF INDIA JABALPUR MADHYA PRADESH OF FAMILY REDUVIIDAE

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ABSTRACT

The paper deals with the study of 53 species of assassin bugs belonging to 29 genera under the 7 subfamilies of Reduviidae from Madhya Pradesh, subfamily Harpectorinae being dominant with 14 species while subfamily Salyavatinae with only 1 species. Subfamily Reduviinae following these with 13 species.

Keywords: *Reduviidae, hemiptera, madhya pradesh.*

INTRODUCTION

Reduviidae family is represented globally by 6878 species/subspecies under 981 genera belonging to 25 subfamilies of these,465 species under 144 genera belonging to 14 subfamilies are recorded from India. Earlier work on Reduviidae of central India were published by Ramakrishna et al. followed by the works of Chandra. Chandra *et al*. 2020 and Chandra and Kushwaha, 2019 from Madhya Pradesh.

Systematic accounts

RESULTS AND DISCUSSION

Subfamily Tribelocephalini Villiers, 1943

1. Genus *Tribelocephala* Stal**,** 1853

1. Tribelocephala indica (Walker, 1873)

1873. ***Opistoplatys (Sic) indica*** Walker, 8:20, Sri Lanka,India.

2006. ***Tribelocephala indica :*** Ambrose, 21 (9) : 2388 + xxvii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 11-13 mm.

Distribution: India: Madhya Pradesh (Raisen), Andhra Pradesh, Mizoram and West Bengal.

2. *Tribelocephala comparanda* (Bergroth, 1910)

1910. ***Tribelocephala orientalis*** Distant, 5:182. India. Preoccupied.

2006. ***Tribelocephala comparanda*** : Ambrose, 21 (9) : 2388 + xxvii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Distribution: India: Madhya Pradesh (Hosangabad), Assam and West Bengal.

Subfamily Harpactorinae Reuter, 1887

2.Genus *Coranus* Curtis**, 1833**

3.*Coranus fuscipennis* Reuter**,** 1881

1881. ***Coranus fuscipennis*** Reuter, 12: 275, Sumatra, China.

2006. ***Coranus fuscipennis*** : Ambrose, 21(9) : 2388 + vii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al. 2020).

Length: 10 mm

Distribution: India: Madhya Pradesh (Seoni), Andhra Pradesh, Maharashtra, Meghalaya, Tamil Nadu, Tripura.

4. ***Coranus siva*** Kirkaldy, 1891

1891. ***Coranus siva*** Kirkaldy, in Maldonado.

2006***. Coranus siva:*** Ambrose, 21(9): 2388 +vii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 10 mm.

Distribution: India: Madhya Pradesh (Seoni), Andhra Pradesh, Maharashtra, Meghalaya, Tamil Nadu, Tripura.

3.Genus ***Endochus*** Stal, 1859

5. ***Endochus inornatus*** (Stal, 1866)

1866. ***Endochus inornatus*** Stal, 23 : 270, India.

2006. ***Endochus inornatus*** : Ambrose, 21 (9) : 2388 + viii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 20 mm.

Distribution: India: Madhya Pradesh (Panna), North India, Tamil Nadu, Uttar Pradesh.

4.Genus ***Euagoras*** Burmeister, 1835

6.*Euagoras plagiatus* (Burmeister, 1834)

1834. ***Zelus plagiatus*** Burmeister, 16 : 303.

2006. ***Euagoras plagiatus*** : Ambrose, 21 (9) : 2388 + viii-ix.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 13 mm.

Distribution: India: Madhya Pradesh (Chhindwada), Andaman Islands, Tamil Nadu, Mizoram, Uttarakhand and West Bengal.

5. Genus ***Rhynocoris*** Kolenati, 1857

7. ***Rhynocoris costalis*** (Stal, 1866)

1866. ***Reduvius costalis*** Stal, 23 : 285, West Bengal.

2006. ***Rhynocoris costalis :***Ambrose, 21 (9) : 2388 + xi.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 14 mm.

Distribution: India: Madhya Pradesh (Chhindwada, Raisen, Katni), Andaman Islands, Tamil Nadu, Mizoram, Uttarakhand and West Bengal.

8 . ***Rhynocoris fuscipes*** (Fabricus, 1787)

1787.***Reduvius fuscipe***, 2 : 312. India Oriental,China.

2006. ***Rhynocoris fuscipes :***Ambrose, 21 (9) : 2388 + xi.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 16 mm.

Distribution: India: Madhya Pradesh (Jabalpur), Andhra Pradesh, Tamil Nadu, Mizoram, and West Bengal.

9. ***Rhynocoris marginatus*** (Fabricius, 1794)

1794. ***Reduvius marginatus*** Fabricus, 4: 196, India.

2006. R***hynocoris marginatus :*** Ambrose, 21 (9) : 2388 + xi.

Material examined: Recorded from literature (Jahan et al.2024 and Mukherjee et al.2020).

Length : 20 mm.

Distribution: India: Madhya Pradesh (Chhindwara, Panna,Raisen), Andhra Pradesh , Tamil Nadu, Mizoram, Sikkim, Assam, Delhi, and West Bengal.

10. ***Rhynocoris squalus*** (Distant, 1904)

1904. ***Harpacter squalus*** Distant, 2: 333, Sikkim.

2006. ***Rhynocoris squalus*** : Ambrose, 21 (9) : 2388 + xii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 21 mm.

Distribution: India: Madhya Pradesh (Chhindwara, Panna,Raisen), Andhra Pradesh , Tamil Nadu, Mizoram, Sikkim, Assam, Delhi, and West Bengal.

6.Genus ***Sphedanolestes***

11. ***Sphedanolestes variabilis*** (Distant, 1904)

1904. ***Sphedanolestes variabilis*** Distant, 2 : 342, Tamil Nadu (Nilgiri hills).

2006. ***Sphedanolestes variabilis*** : Ambrose, 21 (9) : 2388 + xiii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 8 mm.

Distribution: India: Madhya Pradesh (Chhindwara), Chhattisgarh, Karnataka, and Tamil Nadu.

12. ***Sphedanolestes indicus*** (Reuter, 1881)

1881. ***Sphedanolestes indicus*** Reuter, 12: 289, India.

2006. ***Sphedanolestes indicus*** Ambrose, 21 (9): 2388 + xiii.

Material examined: Recorded from literature (Jahan et al. and Mukherjee et al.2020).

Length: 12.5 mm.

Distribution: India: Madhya Pradesh (Chhindwara), Meghalaya, Sikkim, Karnataka, and Tamil Nadu.

7. Genus: ***Sycanus*** Amyot & Serville, 1843

13. ***Sycanus pyrrhomelas*** (Walker, 1873)

1873. ***Sycanus pyrrhomelas*** Walker, 8: 85, India, Myanmar.

2006. ***Sycanus pyrrhomelas:*** Ambrose, 21 (9): 2388 + xiv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 22 mm.

Distribution: India: Madhya Pradesh (Raisen), Chhattisgarh, Karnataka, and Tamil Nadu.

14. ***Sycanus collaris*** (Fabricius, 1785)

1785. ***Reduvius collaris*** Stoll, pp. 152, 163, pl. 38, Fig. 275, pl. 41, Fig. 295 nomen nudum.

2006. ***Sycanus collaris***: Ambrose, 21 (9): 2388 + xiv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 25 mm.

Distribution: India: Madhya Pradesh (Umaria), Meghalaya, Sikkim, Karnataka, Tamil Nadu, Andhra Pradesh, Assam and West Bengal.

8. Genus: ***Lophocephala*** (Laporte, 1833)

15. ***Lophocephala guerini*** (Laporte, 1833)

1833. ***Lophocephala guerini*** Laporte, p. 12, Sri Lanka.

2006. ***Lophocephala guerini***: Ambrose, 21 (9): 2388 + x.

Material examined: Recorded from literature (Jahan *et al*. 2024 and Mukherjee *et al*.2020).

Length: 16 to 17mm.

Distribution: India: Madhya Pradesh (Jabalpur), Meghalaya, Jammu and Kashmir, Sikkim, Karnataka, and Tamil Nadu.

9 .Genus: ***Polididus,*** Stal, 1858

16. ***Polididus armatissimus*** (Stal, 1859)

1855. ***Reduvius policanthatus*** Montrouzier, 7: 109. *Woodlark Is. Schouteden* 1970a, 51: 116 (:13), considered as synonyms of ***P. armatissimus.***

2006. ***Polididus armatissimus:*** Ambrose, 21 (9): 2388 + xi.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 10 mm.

Distribution: India: Madhya Pradesh (Chhindwara, Seoni, Shivpuri), Meghalaya, Maharashtra, Manipur, Mizoram, Sikkim, Karnataka, and Tamil Nadu.

Subfamily: Stenopodainae

10. Genus ***Oncocephalus*** (Stal, 1855)

17. ***Oncocephalus annulipes*** (Stal, 1855)

1855. ***Oncocephalus annulipes*** Stal, 12: 8, 44, Natal

2006. ***Oncocephalus annulipes:*** Ambrose, 21 (9): 2388 + xxiv.

Material examined: Recorded from literature (Jahan et al.2024 and Mukherjee et al.2020).

Length: 14 to 24 mm.

Distribution: India: Madhya Pradesh (Jabalpur), Maharashtra, Manipur, Mizoram.

18. ***Oncocephalus schioedtei*** (Reuter, 1882)

1882. ***Oncocephalus schioedtei,*** Reuter, 1882, 12: 7, 30, India.

2006. ***Oncocephalus schioedtei :*** Ambrose, 21 (9): 2388 + xxv

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 21 mm. Distribution: India: Madhya Pradesh (Chhindwara, Raisen), and Tamil Nadu.

19. *Oncocephalus impudicus* (Reuter, 1882)

1882. ***Oncocephalus impudicus,*** Reuter, 12: 9, 43. Pl. 2, Figs 26, 27, Philippines, India.

2006. ***Oncocephalus impudicus :*** Ambrose, 21 (9): 2388 + xxv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 12-13 mm.

Distribution: India: Madhya Pradesh (Seoni), Manipur, Uttarakhand, and West Bengal.

20. ***Oncocephalus fuscinotum*** (Reuter, 1882)

1882. ***Oncocephalus fuscinotum***, Reuter, 12 : 10, 59, Pl 2, Fig 79, India, West Pakistan.

2006. ***Oncocephalus fuscinotum :*** Ambrose, 21 (9): 2388 + xxv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 11 mm. Distribution: India: Madhya Pradesh (Seoni, Chhindwara, Jabalpur), and Manipur.

11.Genus *Pygolampis* Germar, 1817

21. *Pygolampis unicolor* (Walker, 1873)

1873. ***Pygolampis unicolor*** Walker, 8: 36, North Bengal.

2006. ***Pygolampis unicolor :*** Ambrose, 21 (9): 2388 + xxv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 13 mm. Distribution: India: Madhya Pradesh (Seoni), Manipur, Sikkim, and West Bengal.

22 . ***Pygolampis foeda*** (Stal, 1859)

1859. ***Pygolampis foeda*** Stal, 16 : 379, Phillippines.

2013. ***Pygolampis foeda***: Aukema, Rieger & Rabitsch, 6: 132.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 16 mm. Distribution: India: Madhya Pradesh (Seoni, Chhindwara), Manipur, Tamil Nadu.

12. Genus *Sastrapada* Amyot & Seville, 1843

23. ***Sastrapada baerensprungi*** (Stal, 1859)

1859. ***Harpagochares baerensprungi*** Stal, 16: 381, Sicily.

2013. ***Sastrapada baerensprungi :*** Aukema, Rieger & Rabitsch, 6 : 133.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 14 mm. Distribution: India: Madhya Pradesh (Seoni), Sikkim, Tamil Nadu.

13. Genus *Thodelmus* Stal, 1859

24. *Thodelmus falleni* (Stal, 1859**)**

1859. ***Thodelmus falleni*** Stal, 16: 378, Sri Lanka.

2006. ***Thodelmus falleni:*** Ambrose, 21 (9): 2388 + xxvi.

Material examined: Recorded from literature (Jahan et al.2024 and Mukherjee et al.2020).

Distribution: India: Madhya Pradesh (Seoni, Chhindwara), Andhra Pradesh, Assam, Maharashtra, Tamil Nadu and West Bengal.

Subfamily Ectrichodiinae Amyot & Serville, 1843

14. Genus *Ectrychotes* Burmeister, 1835

25. *Ectrychotes dispar* (Reuter, 1881)

1881. ***Ectrychotes dispar*** Reuter, 12: 304, India.

2006. ***Ectrychotes dispar :*** Ambrose, 21 (9): 2388 + ii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 12 mm. Distribution: India: Madhya Pradesh (Seoni, Jabalpur, Raisen, Sidhi), Andhra Pradesh, Maharashtra, and West Bengal.

15. Genus *Scadra* Stal, 1859

26. ***Scadra annulipes*** (Reuter, 1881)

1881. ***Scadra annulipes*** Reuter, 12: 309, India.

2006. ***Scadra annulipes :*** Ambrose, 21 (9): 2388 + iv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 13 mm. Distribution: India: Madhya Pradesh (Hosangabaad, Raisen), Andhra Pradesh, Kerala, Maharashtra, Tamil Nadu and West Bengal.

Subfamily: Peiratinae

16. Genus *Androclus* Stal, 1863

27. ***Androclus pictus*** (Herrich-Schaeffer, 1848)

1848. ***Pirates pictus*** Herrich-Schaeffer, 8 : 63, Indonesia (Java).

2006. ***Androclus pictus :*** Ambrose, 21 (9): 2388 + xv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 10 mm. Distribution: India: Madhya Pradesh (Sidhi, Shivpuri), Gujarat, Maharashtra.

17. Genus *Catamiarus* Amyot & Serville, 1843

28. ***Catamiarus brevipennis*** (Serville, 1831)

1831. ***Pirates (Peirates*) *brevipennis*** Serville, 23: 217, India.

2006. ***Catamiarus brevipennis:*** Ambrose, 21 (9): 2388 + xv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 20 mm. Distribution: India: Madhya Pradesh (Hoshangabad, Umaria), Karnataka, Tamil Nadu, Uttarakhand.

18. Genus ***Cleptocoris*** Stal, 1866

29. ***Cleptocoris atromaculatus*** (Stal, 1870)

1870. ***Cleptocoris atromaculatus*** Stal, 27: 692, Philipines.

2006. ***Cleptocoris atromaculatus :*** Ambrose, 21 (9): 2388 + xv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 12 mm. Distribution: India: Madhya Pradesh (Narsimpur), Karnataka, Nagaland, Sikkim.

30. ***Cleptocoris lepturoides*** (Wolff, 1804)

1804. ***Reduvius lepturoides*** Wolff, 3: 122, fig. 159, India Orientalis.

2006. ***Cleptocoris lepturoides :*** Ambrose, 21 (9): 2388 + xv.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Distribution: India: Madhya Pradesh (Hosangabad) and Maharashtra.

19. Genus *Ectomocoris* Mayr, 1865

31. ***Ectomocoris quadriguttatus*** (Fabricius, 1781)

1781. ***Reduvius quadriguttatus*** Fabricius, 2: 380, India.

2006. ***Ectomocoris quadriguttatus:*** Ambrose, 21 (9): 2388 + xvi-xvii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 14-17 mm. Distribution: India: Madhya Pradesh (Jabalpur, Seoni), Pondicherry, Tamil Nadu and Maharashtra.

32. ***Ectomocoris simulans*** (Distant, 1919)

1919. ***Ectomocoris simulans*** Distant, (9) 4: 74, South India.

2006. ***Ectomocoris simulans :*** Ambrose, 21 (9): 2388 + xvii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length:16 mm. Distribution: India: Madhya Pradesh (Raisen), Assam, Meghalaya, Uttarakhand and West Bengal.

33. ***Ectomocoris cordiger*** (Stal, 1866)

1866. ***Ectomocoris cordiger*** Stal, 23: 256, India.

2006. ***Ectomocoris cordiger :*** Ambrose, 21 (9): 2388 + xvi.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 15 mm. Distribution: India: Madhya Pradesh (Damoh, Seoni, Raisen) , Assam, Meghalaya, Uttarakhand and West Bengal.

4. ***Ectomocoris elegans*** (Fabricius, 1803)

1803. ***Ectomocoris elegans*** Fabricius, P. 270, Guinea.

2013. ***Ectomocoris elegans:*** Aukema, Rieger & Rabitsch, 6 : 114.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 15 to 18.5 mm. Distribution: India: Madhya Pradesh (Jabalpur), Assam, Meghalaya, Tamil Nadu.

35. ***Ectomocoris tibialis*** (Distant, 1904)

1904. ***Ectomocoris tibialis*** Distant, 2: 293, Maharashtra (Borghat)

2006. ***Ectomocoris tibialis :*** Ambrose, 21 (9): 2388 + xvii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 17 mm Distribution: India: Madhya Pradesh (Chhindwara, Seoni) , Andhra Pradesh ,Assam, Meghalaya, Tamil Nadu.

36. ***Ectomocoris cordatus*** (Wolff, 1804)

1804. ***Ectomocoris cordatus*** Wolff, 4: 163, Sri Lanka.

2006. ***Ectomocoris cordatus :*** Ambrose, 21 (9): 2388 + xv-xvi.

Material examined: Recorded from literature (Jahan et al.2024 and Mukherjee et al.2020).

Length: 12.5 mm. Distribution: India: Madhya Pradesh (Seoni), Punjab, Jammu and Kashmir and Kerala.

20. Genus *Sirthenea* Spinola, 1840

37. ***Sirthenea flavipes*** (Stal, 1855)

1855. ***Sirthenea flavipes*** Stal, 12: 187, Philipines.

2018. ***Sirthenea flavipes*** : Chlond et al., 4520 (1) : 37-38.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 19 to 21 mm. Distribution: India: Madhya Pradesh (Jabalpur) , Andhra Pradesh, Assam, Nagaland, Tamil Nadu.

21. Genus *Spilodermus* Stal, 1868

38. *Spilodermus quadrinotatus* (Fabricius, 1798)

1798. ***Reduvius 4-notatus*** Fabricus, p. 544, India.

2006. ***Spilodermus quadrinotatus :*** Ambrose, 21 (9): 2388 + xviii.

Material examined: Recorded from literature (Jahan et al. 2024 sand Mukherjee et al.2020).

Distribution: India: Madhya Pradesh (Jabalpur) and Tamil Nadu.

2 .Genus *Lestomerus* Amyot & Serville, 1843

39..***Lestomerus sanctus*** (Fabricius, 1787)

1787. ***Reduvius sanctus*** Fabricus, 2 : 310, India.

2006. ***Lestomerus sanctus :*** Ambrose, 21 (9): 2388 + xvii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Distribution: India: Madhya Pradesh (Damoh) , Punjab, West Bengal and Tamil Nadu.

Subfamily: Salyavatinae

23. Genus ***Lisarda*** Stal, 1859

40. ***Lisarda annulosa*** (Stal, 1874)

1874. ***Lisarda annulosa*** Stal, 4 : 83, India.

2006. ***Lisarda annulosa*** **:** Biswas & Bal, p. 272.

Material examined: Recorded from literature (Jahan et al.2024 and Mukherjee et al.2020).

Length: 11 mm. Distribution: India: Madhya Pradesh (Seoni), Meghalaya, Mizoram, and Tamil Nadu.

Subfamily: Reduviinae Latreille, 1870

24. Genus *Acanthaspis* Amyot & Serville, 1843

41. *Acanthaspis fulvipes* (Dallas, 1850)

1850. ***Platymeris fulvipes*** Dallas, 1: 6, Pl.2, Fig.3, India.

2006. ***Acanthaspis fulvipe :*** Ambrose, 21 (9): 2388 + xix.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 25 mm. Distribution: India: Madhya Pradesh (Seoni), Assam, Sikkim, and West Bengal.

42. *Acanthaspis quinquespinosa* (Fabricius, 1781)

1781. ***Reduvius quinquespinosa*** Fabricius, 4: 206, India, China.

2006. ***Acanthaspis quinquespinosa:*** Ambrose, 21 (9): 2388 + xx.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 15 mm. Distribution: India: Madhya

Pradesh (Seoni, Sidhi), Assam, Bihar, Delhi, Meghalaya, Maharashtra, Andhra Pradesh, and West Bengal.

43. ***Acanthaspis trimaculata*** (Reuter, 1887)

1887. ***Acanthaspis trimaculata*** Reuter, 6: 157, India.

2006. ***Acanthaspis trimaculata :*** Ambrose, 21 (9): 2388 + xx.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 21 mm. Distribution: India: Madhya Pradesh (Seoni, Hoshangabad), Andhra Pradesh, and West Bengal.

44. ***Acanthaspis siva*** (Distant, 1904)

1904. ***Acanthaspis siva*** Distant, 2: 265, India, Sri Lanka.

2006. ***Acanthaspis siva:*** Ambrose, 21 (9): 2388 + xx.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 18 mm. Distribution: India: Madhya Pradesh (Seoni, Raisen), Tamil Nadu.

45. ***Acanthaspis luteipes*** (Walker, 1873)

1873. ***Acanthaspis luteipes*** Walker, 7: 175, India.

2006. ***Acanthaspis luteipes :*** Ambrose, 21 (9): 2388 + xix.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length:17 mm. Distribution: India: Madhya Pradesh (Jabalpur), Andhra Pradesh, Sikkim, Tripura, and West Bengal.

46. ***Acanthaspis sexguttata*** (Fabricius, 1775)

1775. ***Acanthaspis sexguttata*** Fabricius, (nec.Amyot & Serville, 1843), p. 832, India.

2006. ***Acanthaspis sexguttata :*** Ambrose, 21 (9): 2388 + xx.

Material examined: Recorded from literature (Jahan et al.2024 and Mukherjee et al.2020).

Length : 16 mm.

Distribution: India: Madhya Pradesh (Shivpuri), Karnataka, Sikkim, Tamil Nadu, and West Bengal.

47. ***Acanthaspis flavipes*** (Stal, 1855)

1855. ***Acanthaspis flavipes*** Stal, 12 :187, India.

2006. ***Acanthaspis flavipes :*** Ambrose, 21 (9): 2388 + xix.

Material examined: Recorded from literature (Jahan et al.2024 and Mukherjee et al.2020).

Length: 16 mm. Distribution: India: Madhya Pradesh (Hoshangabad, Seoni), Maharashtra, Punjab, Tamil Nadu, and West Bengal.

48. ***Acanthaspis rugulosa*** (Stal, 1863)

1863. ***Acanthaspis rugulosa*** Stal, 3 : 49-50, India.

2006. ***Acanthaspis rugulosa :*** Ambrose, 21 (9): 2388 + xx.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 20 mm. Distribution: India: Madhya Pradesh, Maharashtra, Tamil Nadu, and West Bengal.

25. Genus *Empryocoris* Miller, 1953

49. *Empryocoris pelia* (Distant, 1904)

1904. ***Edocla pelia*** Distant, 2: 275, Pegu.

2006. ***Empryocoris pelia:*** Ambrose, 21 (9): 2388 + xxi.

Material examined: Recorded from literature (Jahan et al. and Mukherjee et al.2020).

Distribution: India: Madhya Pradesh (Hoshangabad, Seoni), Maharashtra,Tripura.

26. Genus *Gerbelius* Distant, 1903

50. ***Gerbelius ornatus*** (Distant, 1903)

1903. ***Gerbelius ornatus*** Distant, 47(4): 59, Sri Lanka.

2006. ***Gerbelius ornatus :*** Ambrose, 21 (9): 2388 + xxi.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length : 8 mm. Distribution: India: Madhya Pradesh (Umaria, Seoni), Maharashtra, and Tripura.

27. Genus ***Pasira*** Stal, 1859

51. ***Pasira perpusilla*** (Walker, 1873)

1873. ***Reduvius perpusilla*** Walker, 7: 196, India.

2006. ***Pasira perpusilla :*** Ambrose, 21 (9): 2388 + xxi.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 6 to 6.5mm. Distribution: India: Madhya Pradesh (Raisen), West Bengal, and Tamil Nadu.

28. Genus *Pasiropsis* Reuter, 1881

52. ***Pasiropsis nigerrima*** (Bergroth, 1896)

1896. ***Pasiropsis nigerrima*** Bergroth, 25 : 9, India.

2006. ***Pasiropsis nigerrima :*** Ambrose, 21 (9): 2388 + xxii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 9 mm. Distribution: India: Madhya Pradesh (Seoni), and Maharashtra.

29. Genus *Psophis* Stal, 1863

Plate 1

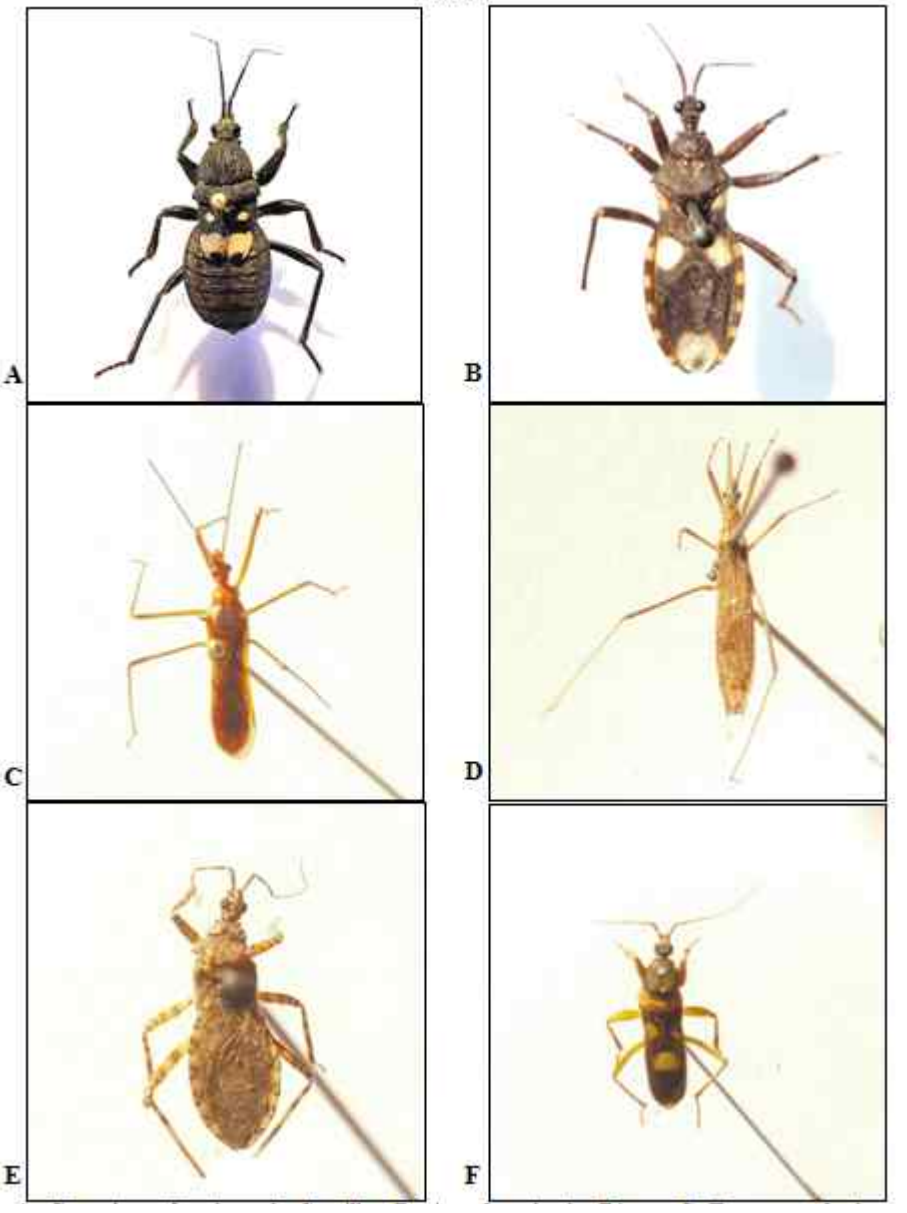

FIG: 1. A. ***Catamiarus brevipennis*** Serville; B. ***Acanthaspis siva*** Distant; C. ***Euagoras plagiatus*** Burmeister; D. ***Sastrapada baerensprungi*** Stal; E. ***Lisarda annulosa*** Stal; F. ***Ectomocoris quadriguttatus*** Fabricius.

Plate 2

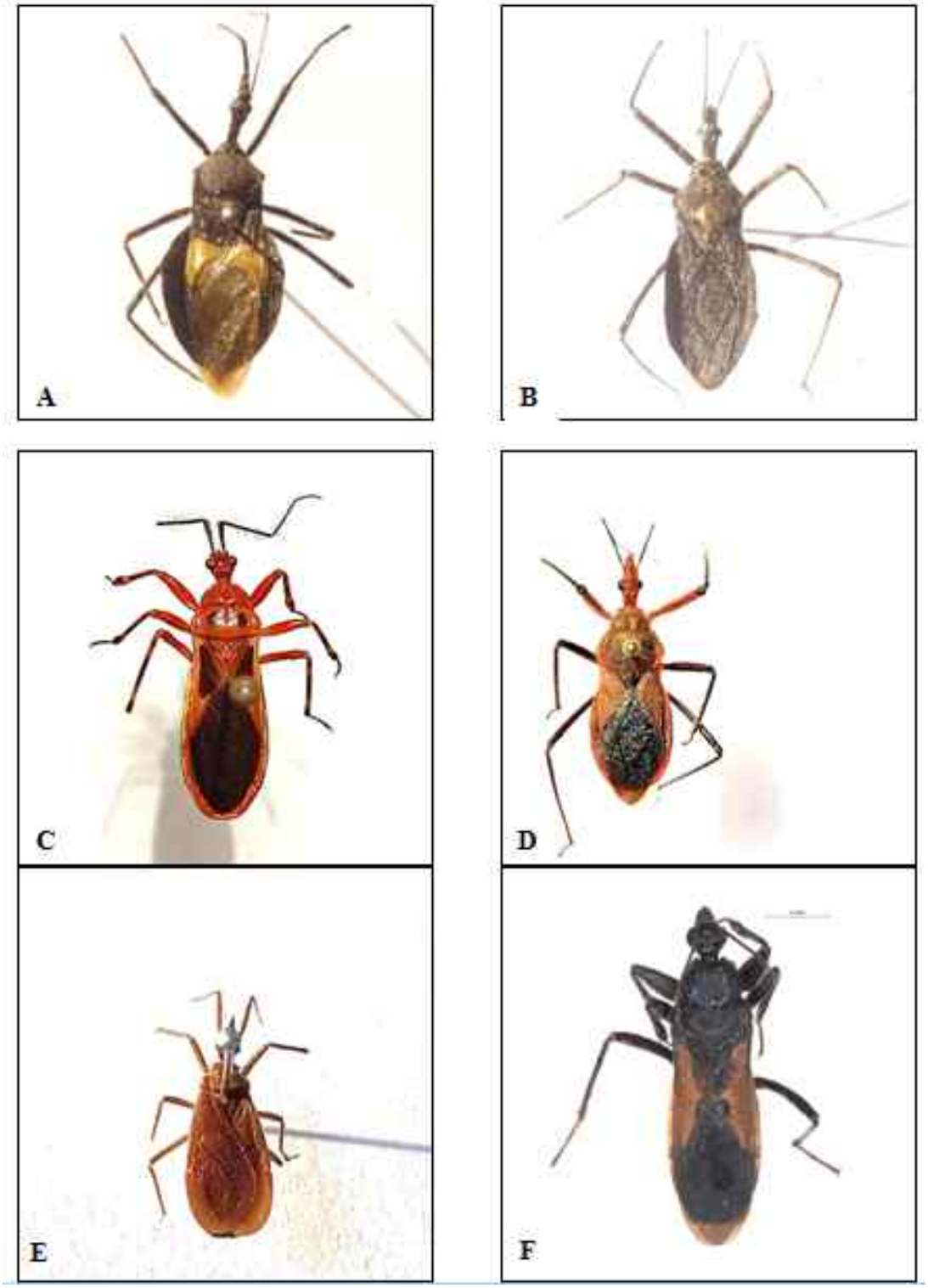

FIG: 2. A. ***Sycanus collaris*** Fabricius; B. ***Oncocephalus schioedtei*** Reuter; C. ***Scadra annulipes*** Reuter: D. ***Rhynocoris marginatus*** Fabricius ; E. ***Tribelocephala indica*** Walker; F. ***Cleptocoris atromaculatus*** Stal.

Plate 3

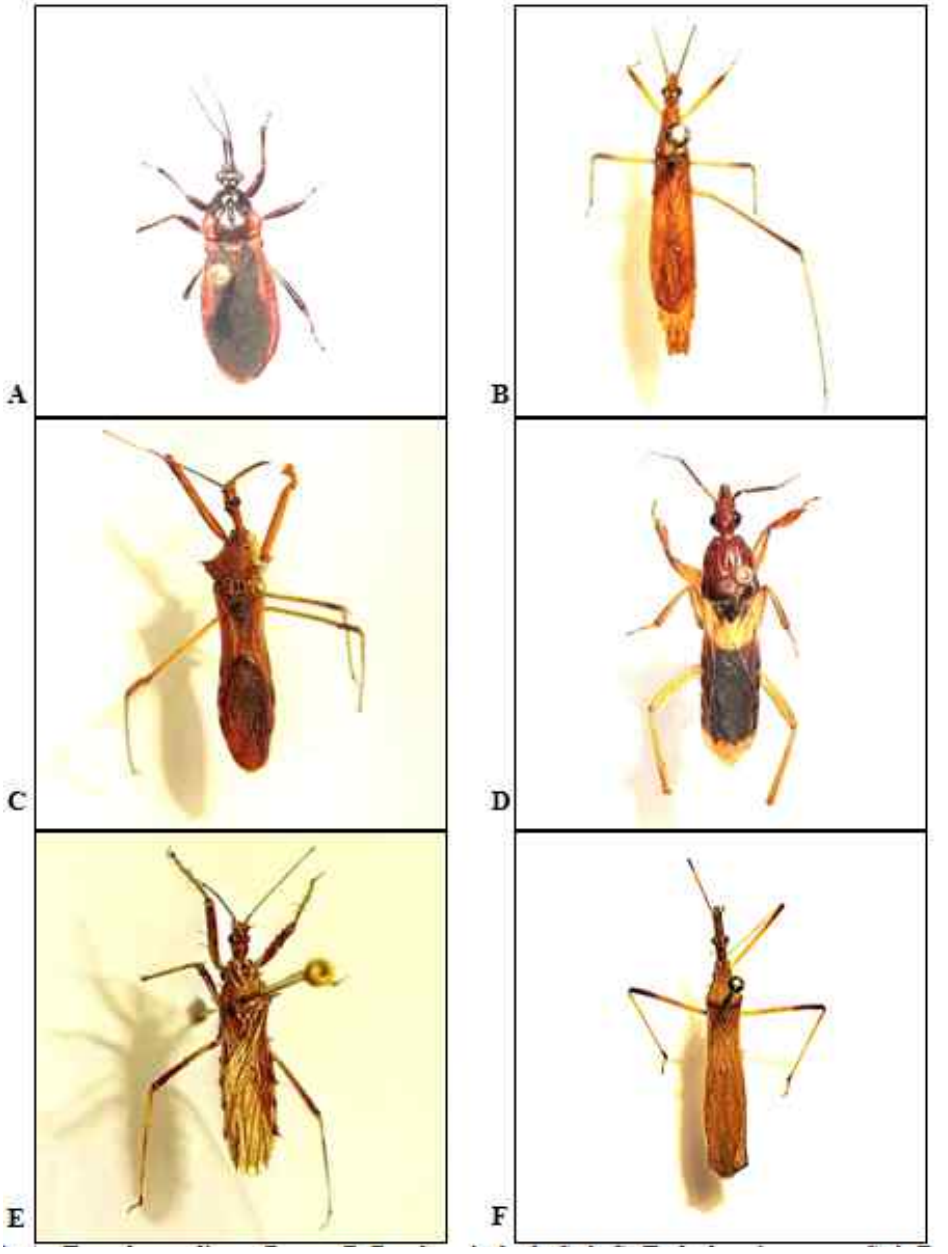

FIG: 3. A. ***Ectrychotes dispar*** Reuter; B ***Pygolampis foeda*** Stal; C. ***Endochus inornatus*** Stal; D. ***Sirthenea flavipes*** Stal; E. ***Polididus armatissimus*** Stal; F. ***Thodelmus falleni*** Stal.

53. ***Psophis erythraea*** (Stal, 1863)

1863. ***Psophis erythraea*** Stal, 3: 53, India.

2008. ***Psophis erythraea :*** Ambrose, 21 (9): 2388 + xxii.

Material examined: Recorded from literature (Jahan et al. 2024 and Mukherjee et al.2020).

Length: 9 mm. Distribution: India: Madhya Pradesh (Jabalpur), and Meghalaya.

Summary

This paper deals with 54 species of assassin bugs belonging to 30 genera from Madhya Pradesh, of which 1 species constitute new records to the state.

Relevant literature references, distribution of each species in different districts of Madhya Pradesh, has been incorporated in the present paper.

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STUDIES ON MINERAL AND MICROBIAL EVALUATION OF MULBERRY AND ALOE-VERA BLENDED POWDER

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ABSTRACT

The investigation was conducted at Division of Post Harvest Management, Chatha, SKUAST-Jammu. For the preparation of blended powder, mulberry and Aloe vera blended in the ratio of 100:0, 90:10, 80:20, 70:30, 60:40 and 50:50, respectively. The processed product was stored at room temperature and subjected to chemical and microbial evaluation at two month interval for a period of six months. With the advancement of storage period, a decreasing trend was observed in ash, calcium and phosphorus content during the three months of storage period. No microbial count was detected upto two month of storage in blended powder. But after four and six months of storage, an acceptable count of microbes was observed.

Keywords : *Mulberry, Microbial, evaluation*

INTRODUCTION

Mulberry is a fast growing woody perennial plant be belongs to the family Moraceae and the genus Morus that contains more than 15 species of deciduous plants. The major ones include Morus Alba, Morus indica, Morus nigra, Morus rubra, Morus australis, Morus atropurpurea, Morus cathayana, Morus notabilis and Morus mesozygia (Sharma *et al*. 2020). Presently, mulberry plants are cultivated mostly for rearing of silkworm only and the soft fruits are generally wasted due to its perishable behavior and poor shelf life. Short shelf life of fresh mulberry fruits after harvest is one of the foremost factor that provide the necessity of developing an economical and efficient preservation process or value-addition (Nayak and Jamuna, 2017). The ethno-botanical usage of mulberry involves the utilization of ripe fruits which are greatly valued for their delicious taste and are also consumed as fresh, dried or after extraction of juice. Mulberry fruits can be well exploited for preparation of numerous value added products, which are of commercial value from the industrial as well as health point of view. Thus, the mulberry-based products include juice (Wang *et al*., 2017), liquor jam, muffin, marmalade, ice-cream, vinegar, wine *etc*., as well as other food and cosmetic products. However, the unripe mulberry fruits are also used for chutney preparation (Yildiz, 2013).

Aloe vera is an important medicinal plant of the family *Lilliaceae* (*Aloe barbadensis* Miller) and is the most popular, commercially important and considered to be the most effective plant (Hes *et al.* 2019 and Rahman *et al*.. 2024). Powder of aloe vera can also be used in ice creams, biscuits, '*lassi*' (yogurt drink), aloe vera '*laddu*' (local sweet), curd *etc*. Aloe gel fillet can be used to make aloe vitamin candies, chewing gum, instant aloe vera tea granules, and aloe gum for sore or bleeding gums, and plenty of other things. While used as a

preservative, the quality of the products was maintained throughout storage and microbial counts remained under control (Javed and Rahman, 2014). Blending also provides the benefits of balancing the strong flavours, astringency, high acidity, bitterness, improving total soluble solids, stabilizing colour and new product development.

MATERIALS AND METHODS

Details of treatments:

The detailed treatments of blended powder are given below

Treatment symbol	Treatments
T_1	100:0:: Mulberry : Aloe Vera
T_2	90:10:: Mulberry : Aloe Vera
T_3	80:20:: Mulberry : Aloe Vera
T_4	70:30:: Mulberry : Aloe Vera
T_5	60:40:: Mulberry : Aloe Vera
T_6	50:50:: Mulberry : Aloe Vera

The blended powder was prepared from mulberry pulp and aloe vera gel as per the standard procedure given by Mahendran (2010). The blended mulberry pulp and aloe vera gel as per treatments was frozen on trays for 5h at -20 ºC. After freezing the samples were transferred to a freeze dryer. The powder was obtained by grinding the dried material in a blender. The blended powder was stored in LDPE pouches under ambient temperature (30-35 ºC) for a period of six months. The samples were analyzed periodically at an interval of 0, 2, 4 and 6 months of storage for chemical and microbiological parameters. The ash, calcium and phosphorus content was estimated as the standard procedure of AOAC (2012). Total plate count of micro-organisms was determined according to method given by Pelczar and Chan (1997). The data obtained was statistically analyzed using CRD factorial for interpretation of results through analysis of variance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Ash and Microbial evaluation of blended powder

The results in Table 1 indicated that ash content of blended powder varied significantly with treatment and storage and decreased significantly with the increase in the level of aloe vera in blended powder. After two months of storage, the treatment T_1 (100:0:: Mulberry : Aloe Vera) recorded the highest ash content of 1.90 per cent followed by the treatment T_2 (90:10:: Mulberry : Aloe Vera) and T_3 (80:20:: Mulberry : Aloe Vera) having ash content of 1.79 and 1.62 per cent, respectively which decreased significantly to 1.64, 1.53 and 1.32 per cent after six months of storage where as the lowest ash content of 0.78 per cent was recorded in T_6 (50:50:: Mulberry: Aloe Vera). On comparing the treatment mean, the maximum treatment mean of 1.83 per cent was recorded in T_1 (100:0:: Mulberry: Aloe Vera) and the minimum mean of 0.98 per cent was recorded in treatment T_6 (50:50:: Mulberry: Aloe Vera).There was a significant decrease in ash content of blended powder with the increase in storage period. However, the interaction effect of treatment and storage was found to be significant at 5 per cent level of significance. The decrease in ash content of blended powder might be attributed to mineral losses from binding of minerals by maillard reaction products during storage (Nadarajah and Mahendran, 2015). Similar findings have also reported by Gupta *et al*. 2023 in osmo-dried peel sticks.

The data in Table 1 revealed that with the increase in concentration of aloe vera, total microbial count decreased significantly in blended powder. Initially all the treatments were found to be free from microbial count. After four months of storage, treatment T_6 (50:50:: Mulberry : Aloe Vera) recorded the lowest total microbial count of 1.14×10^4 cfu/g while as highest was recorded in treatment T_1 (100:0:: Mulberry : Aloe Vera) with total microbial count of 1.65×10^4 cfu/g which increased to 1.32 and 1.87×10^4 cfu/g after six months of storage.

On comparing the treatment means, the

maximum and minimum total microbial count was observed in T_1 (100:0:: Mulberry : Aloe Vera) and T_6 (50:50:: Mulberry : Aloe Vera) having value of 0.89 and 0.61× 10^4 cfu/g, respectively. The findings are in line with Meera *et al.* (2016) in value added probiotic freeze-dried papaya juice powder and in apple-beetroot spread by Gupta *et al.* (2025).

Calcium and Phosphorus

The pooled data in Table 2 showed the effect of treatments and storage period on calcium content of blended powder. The results revealed that the treatments significantly influenced the calcium content of blended powder. Initially, the highest calcium content of 172.95 mg/100 g was recorded in the blended powder developed from treatment T_1 (100:0:: Mulberry : Aloe Vera) followed by treatment T_2 (90:10:: Mulberry : Aloe Vera), T_3 (80:20:: Mulberry : Aloe Vera) and T_4 (70:30:: Mulberry : Aloe Vera) having calcium content of 162.91, 155.24 and 148.88 mg/100 g, respectively and the lowest calcium content of 126.57 mg/100 g was recorded in treatment T_6 (50:50:: Mulberry : Aloe Vera). The highest and lowest calcium content was retained by treatments T_1 (100:0:: Mulberry : Aloe Vera) and T_6 (50:50:: Mulberry : Aloe Vera) having calcium content of 172.14 and 125.73 mg/100 g , respectively after six months of storage period. On comparing the treatment means with each other all treatments were differing significantly at 5 per cent level of significance. During six months of storage period, the calcium content of blended powder decreased significantly from 150.92 to 150.20 mg/100 g during six months of storage. However, the interaction effect of treatment and storage was found to be non- significant at 5 per cent level of significance.

The tabulated data on phosphorus content of blended powder in Table 2 revealed that with the increase in level of aloe vera, the phosphorus content of blended powder decreased significantly at 5 per

Table - 1 : Effect of treatments and storage period on ash (%) and microbial count (×10^4 cfu/g) of blended powder

Treatments	Ash					Microbial count				
	Storage period (Months)					Storage period (Months)				
	0	2	4	6	Mean	0	2	4	6	Mean
T_1 (100:0:: Mulberry : Aloe Vera)	2.03	1.90	1.78	1.64	**1.83**	ND	ND	1.65	1.87	**0.89**
T_2 (90:10:: Mulberry : Aloe Vera)	1.90	1.79	1.61	1.53	**1.70**	ND	ND	1.56	1.72	**0.83**
T_3 (80:20:: Mulberry : Aloe Vera)	1.79	1.62	1.49	1.32	**1.56**	ND	ND	1.41	1.65	**0.77**
T_4 (70:30:: Mulberry : Aloe Vera)	1.57	1.40	1.31	1.20	**1.38**	ND	ND	1.38	1.50	**0.72**
T_5 (60:40:: Mulberry : Aloe Vera)	1.34	1.21	1.10	1.01	**1.17**	ND	ND	1.23	1.41	**0.67**
T_6 (50:50:: Mulberry : Aloe Vera)	1.20	1.02	0.91	0.78	**0.98**	ND	ND	1.14	1.32	**0.61**
Mean	**1.63**	**1.50**	**1.37**	**1.25**				**1.40**	**1.57**	

Factors	CD (5%)	CD (5%)
Treatments	0.01	0.04
Storage	0.01	0.03
Treatments x Storage	0.02	0.09

ND: Not detected

Table - 2 : Effect of treatment and storage on calcium(mg/100 g) and phosphorus(mg/100 g) of blended powder

Treatments	Calcium					Phosphorus				
	Storage period (Months)					Storage period (Months)				
	0	2	4	6	Mean	0	2	4	6	Mean
T_1 (100:0:: Mulberry : Aloe Vera)	172.95	172.61	172.36	172.14	**172.51**	324.01	323.86	323.41	323.11	**323.59**
T_2 (90:10:: Mulberry : Aloe Vera)	162.91	162.64	162.36	163.12	**162.76**	295.59	294.99	294.78	294.41	**294.94**
T_3 (80:20:: Mulberry : Aloe Vera)	155.24	154.97	154.70	154.49	**154.85**	269.61	269.03	268.84	268.60	**269.02**
T_4 (70:30:: Mulberry : Aloe Vera)	148.88	148.42	148.04	147.61	**148.24**	238.04	237.78	237.44	237.11	**237.59**
T_5 (60:40:: Mulberry : Aloe Vera)	138.96	138.61	138.46	138.14	**138.54**	211.12	210.83	210.50	210.16	**210.65**
T_6 (50:50:: Mulberry : Aloe Vera)	126.57	126.21	125.96	125.73	**126.12**	186.38	186.09	185.86	185.31	**185.91**
Mean	**150.92**	**150.57**	**150.31**	**150.20**		**254.12**	**253.76**	**253.47**	**253.12**	

Factors	**CD (5%)**	**CD (5%)**
Treatments	0.02	0.11
Storage	0.01	0.09
Treatments x Storage	0.04	NS

Table - 3 : Cost of production of blended powder

Ingredients	Rate @ `	Blended powder T_4 (70:30:: Mulberry : Aloe Vera)	
		Quantity (g)	Amount (Rs)
(A) Variable cost			
(a) Cost of inputs			
Mulberry fruit	20/Kg	1050g	30.00
Aloe vera	10/ Kg	450g	8.00
LDPE pouches	0.5/pouch	12	6
Total cost			**44.00**
(b) Cost of labour and fuel	@15%		**6.6**
Total variable cost	a+b		**50.6**
(B) Fixed cost			
Machinery depreciation @10% on the total machinery cost of 10,00000 for 300 working days in a year			10,0000
Machinery depreciation for four days			1333.33
(C) Profit @15 of total variable cost and fixed cost	@15%		207.54
(D) GST @12 of total variable cost, fixed cost and profit	@12%		190.98
Grand Total for 360 g product			**1782.45**
Cost per pouch of 30 g			**148.53**

cent level of significance. At the beginning, T_1 (100:0:: Mulberry : Aloe Vera) recorded the highest phosphorus content of 324.01 mg/100 g followed by T_2(90:10:: Mulberry : Aloe Vera) having phosphorus content of 295.59 mg/100 g and the lowest phosphorus content of 186.38 mg/100 g was recorded in T_6 (50:50:: Mulberry : Aloe Vera).

With the advancement of storage, there was a significant decrease in phosphorus content of blended powder. Highest storage mean of 254.12 mg/100 g was recorded during initial month where as lowest of 253.12 mg/100 g was observed at 6 months of storage. However, the interaction effect of treatment and storage was found to be non significant at 5 per cent level of significance. The reason behind the decrease in minerals during storage might be due to interaction of these minerals with other components like proteins and carbohydrates (Mailliard reaction products) making them unavailable (Akhtar *et al*., 2011).

Cost of production of blended powder

The data pertaining to cost of production is presented in Table 3. The cost of production of blended powder T_4 (70:30:: Mulberry : Aloe Vera) which was adjudged as best on the basis of sensory evaluation was based upon the fixed and variable cost of all ingredients used and other factors *viz*., processing charges, packaging materials etc. The cost was calculated on the basis of current market price of the ingredients used. The cost of production per 30 g of blended powder comes to Rs 148.53.

CONCLUSION

The best acceptable powder *i.e*, T_4(70:30:: Mulberry : Aloe Vera) comprised of 148.24 mg/100 g calcium and 237.59 mg/100 g phosphorus. The blended powder retained their quality throughout the storage period of six months with the microbial count of specific limits.

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DIVERSITY AND POLLINATING POTENTIAL OF HEMIPTERAN INSECTS IN THE MAHAKAUSHAL REGION, CENTRAL INDIA

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ABSTRACT

Bees and butterflies entomophily. This act is an key ecosystem resource to plant diversity and crop yield. Few reports discuss Hemipteran insect pollination. The study contemplate the diversity, abundance, and potential of Hemipteran insects as pollinators in the Mahakaushal region of central India. Sampling occurred within steppe, forest borders, and agricultural landscapes from March to September 2025. Insect visitors, such as bees and butterflies, to the flowers of *Calotropis procera, Tridax procumbens, Cassia tora, Lantana camara* and *Ipomoea carnea* in particular were collected and examined microscopically for pollen load. Twenty-eight species of Hemiptera belonging to six families were recorded. The members of Lygaeidae, Miridae and Pentatomidae were highly visited and carried substantial amounts of pollen. These findings allow us to conclude that Hemiptera act as secondary pollinators in semi-arid ecosystems and may contribute to improve the stability of the pollination network in Central India.

Keywords : *Hemipteran, diversity, pollunation*

INTRODUCTION

People consider pollination as one of the most important ecosystem services. More than 75% of all flowering plants reproduce sexually and 35% of food crops grow globally because of it (Ollerton et al., 2011; Potts et al., 2016). Animal-mediated pollination affects genetic diversity and ecosystem resilience in a positive way. Bees, butterflies, flies, and beetles received the focus of most in-depth research, other pollinators like Hemiptera (true bugs) remain badly known (Krenn, 2019). Hemiptera, or hemipterans, are an order with more than 80,000 reported species worldwide, together with the aphids, plant bugs, leafhoppers and shield bugs (Schuh & Slater, 1995). Most individuals eat plants. They feed on plant sap with mouthparts that pierce and suck. However, field observations show that the ant species will visit flowers to feed on nectar, pollen or other exudates (Wheeler, 2001; Sharma & Singh, 2019), and during this feeding may become covered in pollen grains that are carried from flower to flower, making them potential incidental pollinators.

The Upper Maikal region of Mahakaushal area of Central India comprising Jabalpur, Shahdol, Umaria and Dindori districts represents a

transitional vegetation between tropical moist deciduous forests and tropical dry deciduous forests with diverse flora, but the role of non-bee pollinators, especially Hemiptera, in pollination has yet to be studied.

This study seeks to:

- Document the Hemipteran species found visiting the flowers of Mahakaushal.
- How often do they visit flowers, and what is their pollen load?
- Role as pollinators and ecological function.

MATERIALS AND METHODS

2.1 Study Area

The Mahakaushal region (23°29′–24°00′ N, 79°56′–81°30′ E) experience a tropical atmosphere with yearly rainfall of 1100–1300 mm. Sampling was conducted in:

- **Jabalpur (Bargi & Panagar):** agricultural fields and scrubland.
- **Shahdol (Sohagpur):** open grasslands.
- **Dindori:** forest edges near the Narmada Valley.
- **Umaria:** mixed vegetation near Bandhavgarh buffer zone.

2.2 Selection of Floral Species

Five widespread flowering plant species were chosen for their common distribution and known insect attraction:

Plant Species	Family	Flowering Season	Habitat
Calotropis procera	Apocynaceae	March–September	Roadside, wasteland
Tridax procumbens	Asteraceae	Year-round	Grassland
Cassia tora	Fabaceae	July–October	Forest edge
Lantana camara	Verbenaceae	April–December	Shrubland
Ipomoea carnea	Convolvulaceae	March–August	Marshland

2.3 Pollination Potential Analysis

Visitation Frequency: Visits per hour for each flower, noting each plant species.

Pollen Load: Solitary insects wipe in 1 ml of 70% alcohol and someone examined the remains for pollen grains with a microscope.

Behavioural Observations: Count of contacts with flowers, feeding.

Data Analysis: with the Shannon-Weiner diversity index for species diversity, analyze variance (ANOVA) regarding seasonal variability, and correlate floral abundance to Hemipteran visitation.

RESULTS AND DISCUSSION

3.1 Diversity of Hemipteran Visitors

A total of **Twenty eight Hemipteran species** be a part of to **6 families** were identified. The most dominant families were:

Family	Representative Species	No. of Species	Habitat Type
Lygaeidae	*Nysius spp.* , *Spilostethus pandurus*	7	Steppe
Miridae	*Creontiades pallidus* , *Deraeocoris ruber*	5	Cultivated land
Pentatomidae	*Nezara viridula* , *Eysarcoris ventralis*	4	Ecotone (Forest edge)
Coreidae	*Anoplocnemis phasiana*	3	Shrubbery
Reduviidae	*Rhynocoris marginatus*	2	Mixed plants
Cicadellidae	*Cicadella viridis*	7	Grass and vegetation

The Shannon-Weiner diversity index (H′) was **2.83**, show average species diversity.

3.2 Floral Visitation and Behaviour

Hemipteran visits were most regular during morning hours (0800–1000 hrs). Insects perched on petals or discs and repeatedly contacted reproductive organs during feeding. Mean visitation frequency (visits/flower/hour):

Plant	*Mean ± SD*	Dominant Hemipteran Visitor
Calotropis procera	*2.7 ± 0.4*	*Spilostethus pandurus*
Tridax procumbens	3.3 ± 0.5	*Nysius spp.*
Cassia tora	1.9 ± 0.4	*Creontiades pallidus*
Lantana camara	2.2 ± 0.3	*Nezara viridula*
Ipomoea carnea	1.5 ± 0.2	*Anoplocnemis phasiana*

3.3 Pollen Load

Pollen grain counts on individual Hemipterans ranged from **20–145 grains**, with the highest loads observed in *Nysius spp*. and *Spilostethus pandurus*. Microscopic scanning confirmed adherence of pollen on legs, ventral thorax, and antennae. various pollen morphotypes were present, suggesting cross-plant apparition.

3.4 Seasonal Variation

Hemipteran abundance and floral visitation increased clearly throughout **monsoon months (July–September)** due to praising humidity and floral density. ANOVA disclose significant seasonal variation ($F = 7.02, p < 0.05$).

DISCUSSION

The high visitation rates and pollen loads of many Hemipteran species were confirmed, with these insects acting as secondary pollinators. Though a case of incidental pollination, they are an important component of the network due to their abundance and presence throughout the full duration of flowering (Wheeler, 2001; Sharma & Singh, 2019).

4.1 Mechanisms of Pollination

Hemipterans such as the Lygaeidae and Miridae, with piercing-sucking mouthparts which feed on nectar or floral sap, cross-pollinate as they make contact with anthers and stigmas by walking about, or while they probe for food. *Spilostethus pandurus* on *Calotropis procera* and *Nysius spp.* on *Tridax procumbens* were most efficient in pollen carriage.

4.2 Comparison with Other Studies

Similar findings have been reported from African drylands where Hemipterans were observed visiting *Calotropis gigantea* and transferring pollinia (Kevan & Baker, 1983). In Indian ecosystems, Miridae and Lygaeidae have been noted as frequent floral visitors in semi-arid zones (Sharma & Singh, 2019; Rani et al., 2020).

4.3 Ecological Significance

Although Hemipterans are not as efficient as bees, their ecological contribution becomes critical during periods of low bee activity or in disturbed habitats (Proctor et al., 1996). Their role as **hardy, aspiring visitors** helps maintain reproductive success in robust plant species adapted to open or degraded territory (Potts et al., 2016).

CONCLUSION

This study reports, for the first time, the diversity and the pollination potential of the Hemipteran insects of the Mahakaushal region of Central India.

the Hemipteran species, mainly Lygaeidae, Miridae and Pentatomidae, are the major florivores and pollen grains vectors of *Calotropis procera* and *Tridax procumbens*. The study exhibit that the Hemipterans secondarily but significantly pollinate plants as an insect groups contributing in varied floral interchange and maintaining pollination grid throughout semi-arid environments show their importance to regional plant reproduction. To protect biodiversity and hold up pollination networks in Central India, overlooked plant taxa required to be acknowledged and protected.

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DISEASE MANAGEMENT STRATEGIES FOR ENHANCING FARMER'S INCOME

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ABSTRACT

Effective disease management strategies in agriculture plays a critical role in improving crop health, productivity, and ultimately the farmers income. By adopting integrated disease management (IDM) approaches, which combine various control methods, is key. These strategies include timely diagnosis of diseases, utilizing resistant crop varieties, employing cultural practices like crop rotation and proper sanitation, and leveraging biological control agents . By adopting a comprehensive approach to disease management, farmers can significantly enhance their productivity, reduce crop losses, and ultimately improve their income and livelihoods. This abstract explores how modern disease management strategies, supported by agricultural extension services and technological innovations, contribute not only to food security but also to the economic upliftment of the farmers .

Keywords: *Disease, management strategies , farmer's income*

Plant diseases are a major constraint in global agriculture, leading to significant crop losses and reduced farm profitability. Efficient disease management not only helps in minimizing these losses but also improves crop quality and income generation. This chapter explores integrated disease management strategies—ranging from cultural practices to technological innovations—that are economically viable, environmentally sustainable, and scalable for farmers across diverse agricultural systems.

INTRODUCTION

With green revolution, we were able to attain self-sufficiency in food production and the use of pesticides has undoubtedly played a key role in achieving it. But since then, our agriculture has become quite dependent on the use of agrochemicals and pesticides which have posed many potential threats like development of resistance in pests, harmful effects on natural enemies, emergence of new pests and secondary pest resurgence, health hazards for human and animals as well as environmental deterioration. Also, there has been an increase in both the number and the species of the pathogens as well as insect pests that have been attacking a particular crop. A major reason of the indiscriminate and injudicious use of pesticide is the faulty advisement that the farmers avail mostly from the pesticide dealers. An estimated 15-25 percent of potential crop production is lost due to pests, weeds

and diseases. Even if we could save 50% of these losses by crop protection, it will add 70,000 core additional income to our farmers.

When aiming for disease management at a farm level, it should not only be with a view to protect the crop but also with the view to increase farmers' income and reducing the external input use. Trying solely to control the disease, without giving any consideration to other aspects of crop production will be a futile practice that will lead to an increased cost of production rather than increasing the farm income. Disease management along with increasing the farmer's income can only be achieved when the integrated crop management approach is adopted. Sustainable agriculture is approached holistically via integrated crop management, or ICM. In order to provide the most appropriate and secure strategy for long-term gain, it takes into account the circumstances throughout the entire farm, including socioeconomic and environmental aspects. This entails giving careful thought to the selection of a site, management of the soil, seed and planting material, crop nutrition, crop rotation, pest control, water management, and landscape management that is appropriate for the climate and local conditions. ICM is a dynamic system that combines new research and technologies with local knowledge to adjust to changing conditions. Reducing or replacing external farm inputs, like inorganic fertilizers, pesticides, and fuel, with farm-produced alternatives and improved input management is one of ICM's primary goals.

For enhancing the farmer's income, there are basically two ways. Either we plan to increase the crop productivity, which is quite difficult given the present scenario where a stagnation or plateau is reached in terms of yield maximization of most of the crops. Secondly, we can try to reduce the crop losses caused by diseases and pests. Along with it, we should aim for lowering the cost of production by shifting to low/no external input technologies. This includes the optimization of available resources and utilization of on-farm resources to its maximum potential. Following methods should be considered to develop a disease management strategy against a particular disease or all the diseases/pest of a crop that can produce several desirable outcomes and agument the profitibility of the farming.

a. Cultural Practices

Historically, these methods have been foundational to subsistence farming, serving as a tried-and-true approach to preventing crop losses due to diseases and other adverse factors. Despite modern developments in chemical interventions and disease-resistant plant varieties, this traditional strategy is still seen as a critical safeguard, offering vital support for the management of resistant strains and chemically protected crops alike.

The control of plant diseases through cultural practices is built upon the pillars of avoidance, exclusion, and eradication. Their effective deployment necessitates deep insights into pathogen life cycles and crop characteristics. Frequently, agronomic interventions represent the only feasible path to disease control for crops that yield limited returns per unit area or for which no resistant varieties exist.Generally, agronomic practices utilized for disease management are:

1. Crop rotation

A primary method for effective management of most soil-borne diseases is crop rotation. Notable examples of diseases controlled include wilt (pigeon pea, cotton, linseed, sugarcane), red rot (sugarcane), ergot and smut (pearl millet), bunts and flag smut (wheat), leaf smut and bunt (rice), bacterial wilt (potato, tomato), and cereal cyst nematode. The efficacy of crop rotation hinges on selecting appropriate crops for the rotation sequence.

2. Fallowing

An enduring agricultural method involves allowing land to remain uncultivated for a time, a process known as fallowing. This ancient practice is

often part of a broader crop rotation strategy. A key aspect is the repeated disturbance of the soil, which helps expose disease-causing organisms to adverse weather conditions. Specifically, flood fallowing has demonstrated efficacy in managing ailments such as banana Fusarium wilt and root-knot nematodes. Despite its benefits in certain contexts, this technique is generally not recommended for widespread use in agriculture.

3. Tillage practices

Certain tillage practices can significantly mitigate the severity and damage caused by root rot pathogens. Strategies that reduce soil compaction, enhance drainage, and elevate soil temperature have a demonstrable positive impact. Furthermore, post-seedbed preparation activities like breaking hardpans and sub-soiling promote superior plant root development, leading to more robust crop stands. Evidence also indicates that deep plowing and incorporating infected crop residue into the soil can effectively decrease the incidence of various diseases.

4. Mixed cropping

Mixed cropping involves the concurrent cultivation of two or more crops within the same land area, exemplified by combinations such as pigeonpea and sorghum, or cotton and mothbean. This practice offers a distinct advantage by minimizing economic losses should a primary crop succumb to disease. The roots of non-host plants in such systems can serve as physical impediments, hindering pathogen movement, or they may secrete toxic chemicals via root exudates that inhibit fungal growth.

5. Adjustment of date of sowing

Modifying the sowing date can enable crops to bypass critical periods of disease susceptibility. For instance, in northern India, planting peas and chickpeas early in October often results in severe root rot and wilt (caused by a complex of Fusarium, Rhizoctonia, and Sclerotium). This heightened susceptibility is attributed to the prevailing high temperatures and elevated soil moisture conditions during that time.

6. Adjustment of depth of sowing

Altering the depth of sowing can empower the host plant to evade pathogen exposure. Shallow sowing, for example, is effective in reducing damping-off in seedlings by facilitating more rapid emergence. Conversely, placing seeds too deeply can afford pathogens a greater window of opportunity to infect the seed and developing seedlings.

7. Plant spacing and density of stand

The spacing of plants and the overall density of the stand, whether established by seeding rates or transplanting, significantly influence disease incidence, particularly concerning soil-borne pathogens, due to the proximity of roots underground. Overly crowded seedlings tend to remain in a juvenile state for extended periods, and the associated high humidity creates conditions favorable for damping-off fungi to cause prolonged infection.

8. Management of soil water /soil moisture

The management of soil water or moisture plays a crucial role in disease control. While excessive water can sometimes impact pathogen activity, beneficial irrigation is observed in the suppression of common scab in potato. Conversely, Macrophomina phaseolina in potato intensifies under conditions of elevated soil temperature combined with water stress. However, it's also important to recognize that an abundance of moisture can foster a humid microclimate around plants, which benefits many pathogens. Therefore, strategies like proper aeration and canopy management should also be taken into account.

9. Management of host nutrition

Appropriate modifications to host nutrition, including adjustments in fertilizer applications or exogenous nutrient provision, can often decrease disease severity. Pathogens that target new vegetative growth are frequently exacerbated by

high nitrogen levels, as seen in diseases such as late blight of potato and rice sheath blight. In contrast, pathogens that benefit from slow host growth tend to be more severe when nitrogen is deficient; examples include tomato wilt (Fusarium oxysporum f.sp. lycopersici), bacterial wilt of tomato and potato (Ralstonia solanacearum), and root rot caused by Sclerotium rolfsii.

10. Use of Organic amendments

Incorporating organic amendments into the soil is a valuable strategy for enhancing soil structure and fertility, while also suppressing soil-borne plant pathogens. Substances like animal manure, green manure, composts, peats, and integrated crop residues have proven effective against various harmful organisms. These include numerous species of Fusarium, Phytophthora, Pythium, Sclerotinia, and Sclerotium, as well as Rhizoctonia solani, Thielaviopsis basicola, Verticillium dahliae, Meloidogyne species, and Ralstonia solanacearum.

a. Physical Methods:

Hot water treatment, hot air steam treatments are widely used for the control of many seed- borne pathogens. Other physical methods are solar heat treatment, soil solarization, steam sterilization, refrigeration, irradiation, drying, burning, flooding etc. can be used according to the crop and disease.

b. Biological Methods:

Biological control involves the deliberate use of living organisms, whether naturally occurring or introduced, to reduce the activity and populations of specific plant pathogens. Fungal biocontrol agents like Trichoderma. viride, T. harzianum, T. pseudokoningii, T. koningii, Aspergillusniger and among bacteria, Pseudomonas fluorescens and Bacillus subtilis are some of the most widely used commercial biocontrol agents which are effective against a wide range of pathogens.

c. Chemical Methods:

Chemical pesticides may be used for disease management, but only as a last resort. The rational use of fungicides should be done keeping in mind the following points:

i. Accurate diagnosis of plant problems can be accomplished with the help of correct advisory agencies like Kisan Call Centre, Pantnagar Helpline (05944-234810), ATIC, Plant Clinic, KVKS etc.

ii. Use of pesticides based on economic threshold level (ETL) of the pest.

iii. Correct choice of pesticide, its dose, and application technology.

CONCLUSION

Diseases are more damaging when their management is one dimensional instead of a holistic approach of overall crop management. These agricultural practices significantly contribute to overall crop health and foster greater diversity within the soil biota. Implementing them not only helps to reduce disease incidence but also lowers plant protection costs and can enhance farmers' income in a sustainable way.

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EFFECTS OF AGRICULTURAL LANDSCAPE MODIFICATIONS ON INSECT BIODIVERSITY AND PEST OUTBREAKS

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ABSTRACT

Agricultural landscape modifications, including shifts in habitat types, spatial patterns, and farming intensity, strongly influence insect biodiversity and pest dynamics. This review synthesizes research from the past twenty years to examine how various landscape features influence beneficial insect communities and pest outbreaks across global farming systems. Overall, studies show that more complex landscapes tend to support greater insect diversity and improve natural pest control. Yet, the strength and direction of these relationships differ depending on the region, crop type, and farming practices. These insights highlight the importance of incorporating landscape-scale biodiversity management into sustainable agriculture to maintain both productivity and ecological stability.

Keywords : *Agricultural landscape, insect biodiversity, pest outbreaks, Ecological stability.*

INTRODUCTION

Over the years, the expansion of intensive farming has drastically transformed rural landscapes. Fields that were once smaller and more diverse have been consolidated into larger, homogeneous tracts, resulting in decreased habitat diversity and a sharp reduction in natural and semi-natural habitats. These structural shifts have a significant influence on insect diversity, affecting both beneficial species, such as pollinators, and natural enemies, as well as pest populations (Bianchi *et al.,* 2006; Fischer *et al.,* 2023; Tscharntke *et al.,* 2005).

Semi-natural elements like hedgerows, grasslands, and wooded margins continue to provide essential ecosystem functions, offering food, nesting and overwintering habitats for insects, leading to an imbalance in the natural ecosystem (Hani & Boller, 1998; Alignier *et al*., 2014; Benton et al., 2003). Yet, when farming intensifies—through excessive pesticide use or the spread of monocultures—these ecological advantages often diminish, destabilizing natural population control mechanisms (Pandey *et al*., 2022; Rusch *et al.,* 2016).

Beyond that, climate change influences land-use modifications, altering insect phenology, seasonal insect activity, distribution, and biodiversity composition (Kleijn *et al.,*2022; Majeed *et al.,* 2022). In this review, we examine how

such landscape changes collectively influence insect diversity and pest dynamics, and discuss what this means for more resilient pest-management strategies.

MATERIALS AND METHODS

A structured literature search was conducted in Web of Science, Scopus, and PubMed for studies published in the last two decades using the various keywords like "agricultural landscape," "insect biodiversity," "pest outbreaks," "landscape modification," and "natural pest control."

Studies were included if they examined relationships between agricultural landscape structure and insect biodiversity or pest dynamics. The selected studies included peer-reviewed, English-language publications that presented empirical or experimental data from agricultural systems. Research focused solely on urban or non-agricultural environments was excluded.

The reviewed literature was then analyzed qualitatively to identify recurring patterns and underlying mechanisms that connect landscape changes with insect biodiversity and pest regulation across different types of agroecosystems.

RESULTS AND DISCUSSION

Landscape Complexity and Insect Biodiversity

Landscape complexity defined by habitat diversity, spatial configuration, and connectivity strongly promotes insect biodiversity (Sardari *et al.,* 2022). Complex landscapes feature semi-natural habitats and provide essential resources and a habitat for diverse insect communities, particularly pollinators and natural enemies. These habitats improve ecosystem services like pollination and biological pest control. (Hani & Boller, 1998; Alignier *et al*., 2014). However, the extent of these effects varies with landscape context, insect taxa, and management intensity. High pesticide use, even in structurally diverse landscapes, can lead to biodiversity loss and interfere with natural pest control. (Pandey *et al.,* 2022; Jones *et al.*, 2020).

Landscape Simplification and Pest Outbreaks

Simplified agricultural landscapes like monocultures and a lack of non-crop habitats generally lead to higher pest outbreaks. The loss of habitat and alternative prey reduces populations of predators and parasitoids, which leads to a disbalance of natural pest control. (Vialatte *et al*., 2019). This generally drives frequent reliance on chemical control methods, which may further reduce biodiversity and promote pesticide resistance, creating a loop of dependency on chemicals and ecological degradation and imbalance among biodiversity (Rusch *et al.,* 2016).

Role of Semi-Natural Habitats

Semi-natural habitats which is adjacent to croplands act as reservoirs for beneficial insects and sustain populations that can suppress pest outbreaks (Alignier *et al.,* 2014). Features like hedgerows, flower strips, and field margins enhance connectivity among the biodiversity, which will lead to continuity across landscapes. The effectiveness of this connectivity, however depends on various factors like habitat quality, configuration of the landscape, and pesticide drift from adjacent fields (Pandey *et al.,* 2022). Conservation of these habitats is necessary to maintain ecological balance, which leads to long-term pest control efficiency.

Agricultural Practices and Climate Change Interactions

Intensive agricultural practices like frequent pesticide application and soil disturbance can degrade the benefits of landscape complexity as it will disrupt the ecological networks (Pandey *et al.,* 2022). Climate change adds further pressure by altering insect phenology, its distribution, and its trophic interactions (Kleijn *et al.,* 2022). Warming temperatures tend to extend pest breeding seasons, which generally facilitate expansion of range, These changing conditions can sometimes overpower natural enemy populations. So, to build more resilient pest management systems, it is important to combine thoughtful habitat management with climate-adaptive strategies.

Crop Diversification and Agroforestry

Crop diversification and agroforestry can go together to enhance structural and functional landscape complexity for supporting diverse insect communities, as this will provide proper habitat to support the biodiversity (Smith *et al.,* 2023). Mixed cropping systems and tree-based farming not only provide continuous floral resources and microclimatic stability but also a sheltering place to harbor beneficial insects. Such systems can help us to cut down on pesticide use, strengthen ecological resilience, and support healthier soils, all of which will align with the broader goals of sustainable intensification.

CONCLUSION

Agricultural changes in landscape design have a major influence on insect biodiversity and the dynamics of pest outbreaks. Increasing landscape complexity through conserving semi-natural habitats, diversifying cropping systems, and limiting pesticide use can promote natural pest control and help to build more resilient farming ecosystems. In contrast, simplified and intensively managed landscapes lead to ecological imbalance and reduce beneficial insect populations, and increase pest pressure. To seek long-term productivity, it's crucial to integrate biodiversity conservation into agricultural planning and management. Encouraging habitat diversity and ecological connectivity across farmlands will not only lessen dependence on chemical control but also enhance ecological stability and support both environmental sustainability and agricultural resilience in a changing global climate.

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THE ARTIFICIAL INTELLIGENCE (AI) REVOLUTION IN INFORMATION ACCESS: A PARADIGM SHIFT

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ABSTRACT

RThe traditional image of a library, a quiet haven filled with rows of books and studious silence, is rapidly evolving. At the forefront of this transformation is Artificial Intelligence (AI), a technology revolutionizing how libraries manage, disseminate, and interact with information. Far from replacing the indispensable human element, AI is augmenting library facilities, making them more efficient, accessible, and user-centric, thereby ushering in a new era of knowledge discovery.One of the most significant impacts of AI on library facilities is the enhancement of information retrieval and discovery. AI-powered search engines and recommendation systems are moving beyond simple keyword matching. By leveraging natural language processing (NLP) and machine learning algorithms, these systems can understand user intent, analyze content context, and provide highly relevant results. Imagine a student researching "the socio-economic impact of renewable energy in developing nations." An AI-driven system could not only pinpoint relevant academic papers but also suggest related datasets, policy documents, and even experts in the field, all while learning from the user's past interactions to refine future recommendations. This personalization transforms the search experience from a tedious task into an intuitive journey of discovery.

Keywords: *Artificial intelligence, ai revolution, information access, ai transformation*

INTRODUCTION

The idea of artificial beings with intelligence or consciousness appears in ancient myths and stories, from automatons in Greek mythology to the Golem of Jewish folklore.These narratives reflect a long-standing human fascination with creating intelligent life. The 17th century saw advancements in mechanical calculators (Pascal, Leibniz). Later, Charles Babbage's Analytical Engine in the 19th century conceptualized a general-purpose programmable computer, a precursor to modern computing. The term "robot" itself was coined by Czech playwright Karel Capek in his 1921 play "R.U.R." (Rossum's Universal Robots), introducing the idea of artificial, humanoid workers.

Artificial Intelligence is not just a technological upgrade for libraries; it represents a fundamental shift in how information is accessed, managed, and delivered. By embracing AI, libraries are entering a new era where they can offer more personalized, efficient, and accessible services, solidifying their role as indispensable pillars of knowledge and community in the 21st century. While navigating the inherent challenges is crucial, the transformative potential of AI promises a future where libraries are more dynamic, responsive, and relevant than ever before. AI is streamlining collection management and development. Libraries grapple with vast and

ever-growing collections, both physical and digital. AI can automate routine tasks like cataloging and metadata generation, drastically reducing the manual effort involved and improving data accuracy. By analyzing circulation data, usage patterns, and emerging trends, AI-powered predictive analytics can help librarians make informed decisions about acquisitions, ensuring that collections align with user preferences and future demands. This data-driven approach optimizes resource allocation, preventing underutilized resources and maximizing the value of every acquisition.

The realm of user services is also being profoundly reshaped by AI. Chatbots and virtual assistants, trained on extensive library knowledge bases, can provide instant, 24/7 assistance to patrons. From answering basic inquiries about library hours or borrowing policies to guiding users through complex research queries or even facilitating book reservations, these AI tools free up librarians to focus on more complex, personalized interactions requiring human expertise and empathy. Moreover, AI is significantly enhancing accessibility. Text-to-speech, speech-to-text, and real-time language translation functionalities powered by AI break down barriers for users with disabilities or those from diverse linguistic backgrounds, ensuring equitable access to information.Artificial intelligence (AI) is ushering in a transformative era for information access, fundamentally changing how we find, process, and interacts with knowledge. This isn't just about faster searches; it's about a more intelligent, personalized, and efficient information ecosystem.

Importance of Artificial intelligence (AI) in Information Access

- Libraries, traditionally revered as quiet sanctuaries of knowledge, are undergoing a profound transformation in the digital age. Far from being rendered obsolete by the internet, they are embracing technological advancements to enhance their core mission of information access and community engagement. Among these advancements, Artificial Intelligence (AI) stands out as a pivotal force, reshaping every facet of library facilities, from back-end operations to the very experience of their patrons. The integration of AI is not merely a futuristic fantasy; it is a present reality that promises to make libraries more efficient, personalized, and relevant than ever before.
- One of the most immediate and impactful roles of AI in libraries is the revolution of information retrieval and discovery. Traditional search methods, often keyword-based, can be cumbersome and may miss nuances in user queries. AI, particularly through Natural Language Processing (NLP) and machine learning, allows for a more intuitive and intelligent search experience. Patrons can articulate their needs in natural language, and AI algorithms can understand the intent behind their words, retrieving highly relevant resources that might otherwise be overlooked. This extends to personalized recommendation systems, where AI analyzes borrowing history, search patterns, and even explicit preferences to suggest books, articles, or other media tailored to individual interests, fostering deeper engagement with the library's vast collections.
- Beyond discovery, AI significantly streamlines library management and technicalservices. Cataloging, a meticulous and time-consuming process, can be greatly accelerated by AI. Automated metadata generation, subject heading assignment, and classification of materials reduce manual workload, ensuring consistency and accuracy in the library's catalog. AI can also assist in inventory and stock management, optimizing shelf space, identifying rarely used resources, and predicting demand for specific materials, leading to more efficient resource allocation. Furthermore, AI-powered tools can assist in digital preservation, helping to digitize and manage vast archives, ensuring that fragile or

rare materials remain accessible for future generations.

- The patron experience is also being profoundly enhanced by AI. Virtual assistants and chatbots, available 24/7, can answer a multitude of common queries, guide users through library resources, provide real-time assistance, and even facilitate basic transactions like renewals or reservations. This frees up librarians to focus on more complex research assistance and community programming. For users with disabilities, AI offers crucial accessibility features, such as automatic text-to-speech conversion, image recognition for generating textual descriptions, and real-time language translation, making information truly equitable.
- However, the integration of AI in libraries is not without its challenges. Ethical considerations surrounding data privacy and algorithmic bias are paramount. Libraries, as custodians of user data, must ensure robust security measures and transparency in how AI systems collect and utilize personal information. There is also the potential for algorithmic bias to reinforce existing societal inequalities if AI is trained on skewed data, leading to unfair or discriminatory outcomes in recommendations or search results. Furthermore, the financial investment required for AI infrastructure and ongoing maintenance can be substantial, posing a hurdle for smaller or underfunded institutions. Finally, the fear of job displacement among library staff is a valid concern, necessitating thoughtful strategies for retraining and re-skilling librarians to work alongside AI tools, shifting their roles towards more complex, human-centric tasks.
- In conclusion, Artificial Intelligence is undeniably poised to play an increasingly central role in the evolution of library facilities. From intelligent information retrieval and streamlined operational efficiency to enhanced accessibility and personalized user experiences, AI offers transformative potential. While challenges related to ethics, finance, and human integration must be carefully navigated, the proactive and responsible adoption of AI can empower libraries to not only maintain their vital function as knowledge hubs but also to innovate and adapt, ensuring their continued relevance and value in an ever-evolving information landscape.

Revolutionizing Information Access with Artificial Intelligence

- **Smarter Search and Retrieval:**
  - **Beyond Keywords:** Traditional search engines relied heavily on keyword matching.AI, particularly Natural Language Processing (NLP) and deep learning, allows search engines to understand the *intent* and *context* of a query, going beyond exact words to deliver more relevant results.This means you can ask questions in natural, conversational language and get accurate, nuanced answers.
  - **Personalization:** AI algorithms analyze user behavior, search history, and preferences to curate highly personalized content.This makes it easier to find relevant information quickly, though it also raises concerns about "filter bubbles" where users are primarily exposed to information that aligns with their existing beliefs.
  - **Summarization and Condensation:** With the overwhelming volume of information available, AI tools can summarize long articles, videos, and documents into digestible formats like executive summaries, bullet points, or short clips, helping users cut through the noise.
  - **Multimodal Search:** Information access is no longer limited to text. AI enables users to search and learn using images, videos, and even real-world objects, creating richer and more intuitive interactions.
- **Enhanced Accessibility and Interaction:**
  - **Voice-Activated Assistants:** The rise of voice assistants like Siri, Alexa, and Google Assistant allows users to interact with information in a more intuitive, hands-free way, making

information more accessible for diverse users, including those with visual impairments or motor disabilities.

- **Real-Time Translation:** AI-powered translation tools are breaking down language barriers, providing near-instantaneous translation of text and spoken words, and opening up access to knowledge for a global audience.
- **Conversational AI:** Tools like ChatGPT and Google's AI summaries provide direct, synthesized responses, reducing the need for users to navigate to original source websites.This shifts the user experience from active searching to a more conversational reception of synthesized knowledge.

- **Transforming Information Management and Security:**

- **Automated Data Processing:** AI can automate repetitive tasks like cataloging, classification, and data extraction from documents, streamlining operations and freeing up human resources for more complex tasks.
- **Predictive Analytics:** AI-powered information systems can analyze vast amounts of data to predict trends, identify potential issues (e.g., in cybersecurity or equipment maintenance), and inform decision-making across various industries.
- **Enhanced Access Control:** AI is revolutionizing identity and access management by analyzing behavioral patterns, contextual signals, and access anomalies to provide more accurate and real-time security, preventing unauthorized access and detecting threats.
- **Combating Misinformation:** While AI can also be used to generate fake content, it plays a crucial role in detecting patterns of fake news, flagging deepfakes, and verifying sources.

The Future of Information Access with AI:

- **More Seamless Integration:** AI will become even more embedded in our daily lives, with user-friendly platforms allowing non-experts to leverage AI for personal, professional, and creative projects.
- **Highly Personalized and Contextual Experiences:** Information systems will become even more adept at understanding individual needs and delivering highly relevant, context-aware information.
- **Advanced Decision-Making:** AI will enable systems to analyze massive datasets and make increasingly informed and rational decisions, driving efficiency and innovation across sectors.
- **Ethical Considerations:** As AI becomes more pervasive, critical imperatives include establishing robust citation mechanisms to attribute original content, addressing algorithmic bias, and ensuring data privacy.

Beyond these tangible benefits, AI is fostering innovation and new opportunities within library facilities. AI can assist in the digitization and preservation of rare and fragile materials, ensuring their longevity and accessibility for future generations. immersive learning experiences can be created through virtual reality (VR) powered by AI, allowing users to explore historical archives or scientific concepts in dynamic, engaging ways. Libraries are also leveraging AI for proactive community engagement, using data analytics to understand community needs and tailor programs and events accordingly.

However, the integration of AI in libraries is not without its considerations. Ethical concerns surrounding data privacy, algorithmic bias, and the potential impact on human agency must be carefully addressed. Libraries, as trusted institutions, have a crucial role to play in ensuring the responsible and equitable implementation of AI, educating users about its capabilities and limitations, and fostering digital literacy.

The future of AI in library services points towards even more seamless integration and sophistication. We can anticipate more advanced predictive analytics that not only forecast user needs but also

inform collection development and strategic planning. The use of AI in digital preservation will become increasingly vital, ensuring that historical and rare materials are digitized, preserved, and made accessible for future generations. Libraries will continue to evolve as centers for AI literacy, offering workshops and programs to help communities understand and critically engage with AI technologies.

CONCLUSION

Artificial Intelligence is not just a technological add-on for libraries; it is a transformative force that is fundamentally redefining their role in the information age. By automating routine tasks, enhancing information discovery, personalizing user experiences, and improving accessibility, AI is empowering libraries to become even more dynamic, relevant, and vital hubs of knowledge. As AI continues to evolve, libraries stand poised to embrace its potential, enriching the lives of their patrons and safeguarding their position as indispensable pillars of learning and intellectual growth in a rapidly changing world.

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INDIGENOUS TECHNICAL KNOWLEDGE FOR SUSTAINABLE AGRICULTURE AND LIVELIHOOD SECURITY

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ABSTRACT

Indian farmers have always engaged in traditional farming methods. Indigenous knowledge is the distinctive, customary, local knowledge that has grown up around the particular circumstances of men and women in a given region. India is the resident of over 700 indigenous groups, which represent approximately8 % of the overall population of the nation. These groups posses a wealth of traditional knowledge and package practices that have been transmitted across generations. Indigenous population in India contributes significantly to the enhancement of the nation's cultural and ecological diversity. They hold knowledge regarding medicinal plants, sustainable farming techniques, and resource management strategies that are oftendisregarded. Indigenous agricultural practices focus on organic methods, promoting soil health and sustainable food production with crop diversity and rotation. These technologies enhance soil fertility, resilience against climate change, and food security while safeguarding the environment. Indigenous communities innovate with water management techniques like rainwater harvesting and aquifer management for better resource control.Designing sustainable agricultural systems can benefit greatly from the use of indigenous knowledge, which raises the possibility that rural communities will embrace, create, and sustain innovations and interventions. Indigenous wisdom from around the world, properly documented, validated, then shared and exchanged globally to produce high-quality food sustainably with less negative environmental impact. Government programs and R&D initiatives ought to reach.Existing studies in this domain have substantiated the significance of indigenous knowledge in relation to environmental sustainability, while incorporating, reinterpreting, and merging these knowledge frameworks into conventional policy and programming to improve the overall sustainable development of the global community.

Keywords : *Sustainability, Indigenous technical knowledge, organic methods, indigenous communities, Sustainable farming, livelihood.*

INTRODUCTION

Indigenous Technical Knowledge (ITK) refers to the skills, experiences, and insights developed by indigenous communities through long-term interaction with their environment. This knowledge is often made up of unique techniques, practices, skills and cultural elements specific to each communities*(Ebenzer Osei Jones, 2024*).As *Ghosh (2011)* highlights, indigenous knowledge is inherently local and traditional, originating and evolving within distinct communities native to particular regions. *Devi et al. (2014)* further emphasize that indigenous knowledge consist of skill and practices that have developed and

deepened over time through the accumulation of experiences and insight within native communities. Seeing indigenous knowledge and scientific knowledge as two separate and isolated entities does not describe the real situation and potential for integration in environmental governance and sustainable development (*Agrawal, 1995)*.

As These traditional practices encompass a variety of techniques related to agriculture, resource management, food security, and ecosystem preservation. It is a legacy passed down from one generation to the next generation and served as a repository of knowledge, skill and techniques for the effective management of farming system, transmitted through the exchange of culture and traditional information *(Singh, 2007)*. According to *Ghale & Upreti, 2000* unsustainable and expensive foreign technology is replacing local agricultural practices, on which the majority of poor farmers rely, damaging the resources and productivity potential of rural poor farmers. This paper aims to examine the role of ITK in promoting sustainable agriculture and enhancing livelihood security. Drawing upon case studies from various regions, we explore how ITK can complement modern agricultural systems, conserve biodiversity, enhance resilience to climate change, and ensure the long-term well-being of rural communities. We also discuss the challenges of integrating ITK into contemporary agricultural policies and practices and suggest pathways for revitalizing and mainstreaming these valuable knowledge systems. Sustainable agriculture and livelihood security are central to addressing global food security, poverty, and environmental challenges. While modern agricultural techniques have undoubtedly contributed to increased food production, they often come with negative environmental, social, and economic impacts. Conversely, Indigenous Technical Knowledge (ITK), which has been refined over centuries, offers valuable solutions for sustainable agricultural practices and resilient livelihoods.

Incorporating ITK into agricultural policies can lead to more sustainable, inclusive, and culturally appropriate development programs that support livelihood security (F. M. A. Abdi and H. G. Osman, 2016). Indigenous peoples around the world have developed practices that are adapted to local ecological conditions and are closely linked to cultural traditions and community values. Indigenous knowledge systems, particularly those related to local climate patterns and indigenous varieties of crops, are crucial for enhancing resilience to climate change and improving the adaptability of farming systems (*M. D. R. Joshi and N. K. Shah, 2012*). The integration of ITK with modern agricultural practices is increasingly recognized as a means to achieve sustainable development goals (SDGs) in rural areas. M. R. A. N. Hossain and P. S. R. Raju (2010) identifies how indigenous practices promote ecological balance and increase resilience to environmental changes, thereby securing rural livelihoods.This paper explores the contributions of ITK to sustainable agriculture and livelihood security, focusing on its role in improving food production, resource management, biodiversity conservation, climate adaptation, and community empowerment. We also address the challenges and opportunities associated with incorporating ITK into contemporary agricultural systems.

The Role of ITK in Sustainable Agriculture

1. Biodiversity Conservation

We are at a crucial juncture in time due to the interplay of climate change, biodiversity loss, and the socio-ecological changes that accompany it. It is evidently too late to stop ecological change on a global scale (Marquest *et al. (2019)*. An estimated one million species on Earth are in danger of going extinct (Diaz *et al. (2019)*, and climate change is already having an impact on around 80% of the ecological processes that support ecosystem functioning and the related services that people depend on (*Scheffers et al. (2016)*. Indigenous

technical knowledge emphasizes the importance of maintaining biodiversity and ecosystem health, which are critical for sustainable agricultural systems. Traditional knowledge systems include techniques such as crop rotation, agroforestry, polyculture, and the preservation of indigenous seed varieties, all of which contribute to a more biodiverse and resilient agricultural landscape. Biological diversity is now threatened by extinction. According to *Quiroz (1996),* biological diversity and cultural diversity are two sides of the same coin. By maintaining diverse ecosystems, ITK-based practices help control pests, prevent soil degradation, and improve soil fertility. With cultural and environmental changes, both biodiversity and the indigenous technical knowledge systems vital to the sustainability are being lost at an incredible rate (*Hoverkort and Millar, 1994*). *Mathias- Mundy et al. (1992)* suggested that how indigenous agroferestry system enables farmers and pastoralist to preserve a diverse array of trees. For instance, agroforestry systems, where trees are integrated with crops, not only enhance biodiversity but also provide additional products like fruits, nuts, and timber, improving farmers' livelihoods. *Alvera (2013)* also highlighted that indigenous food production systems exhibits a notable level of sophistication, making substantial contribution to food security at both the household and community level.

2. Soil and Water Management

For agricultural growth, indigenous agricultural knowledge has long been a vital resource. The link between living things and their surroundings is the subject of a systematic and collective body of knowledge, practices, and beliefs that are evolving via adaptation and spreading through generations via cultural transmission *(R.D. Tella, 2007).* Without access to outside resources, inputs, or scientific expertise, farmers have been using their indigenous knowledge to produce food crops in a variety of environmental circumstances and with seasonal unpredictability *(A. Maroyi, 2012).* In semi-arid regions that are prone to drought, boosting water infiltration and replenishing nutrients are crucial for raising soil production and enhancing livelihoods *(Baptista et al., 2015)*. Efforts are being made to improve soil fertility and conserve water in order to implement sustainable food production methods that are both economically and environmentally viable *(Van Beek et al., 2017)*. In dryland regions, combining soil fertility amendments with water harvesting technologies has a potential impact on optimizing dryland crop production *(Mekuriaw et al., 2018)*. Indigenous communities have long utilized sustainable soil and water management practices that improve agricultural productivity and prevent environmental degradation. Practices like terracing, mulching, and traditional irrigation methods are designed to conserve water and soil, reduce erosion, and enhance soil fertility. For example, the "Zai" pits in the Sahel region of Africa, developed by indigenous farmers, are used to enhance soil fertility and water retention in arid areas, allowing crops to grow in conditions that would otherwise be unsuitable. In order to address the issue of soil water scarcity and boost agricultural productivity in semi-arid regions, researchers have looked into a number of different options. Zai pits, semicircular bunds, half moons, and negarims are some methods for conserving soil and water *(Nicol et al., 2015).*In Sri Lanka, as perhaps in other countries, methods for forecasting rain and managing water are typical examples of knowledge that is passed down orally from generation to generation (*Herath T. N., 2001*).

Farmers in India have long used several water harvesting methods, including farm ponds, check dams, shallow wells, diversion canals (khuls), brick lined tanks, and channels. The construction process involved hilly rivers, tank cascades, Bandhara, Khadin, Nolla check, Pat system, Phad system, Chauka system, and Haveli system, among others. The water supply systems of Sindhu Valley civilization, Chola rulers' Grand Ancient system in the 2nd century A.D., and large tanks in the Deccan throughout medieval times continue to serve people

for irrigation, drinking water, and aquaculture.

3. Climate Adaptation and Resilience

One of the most significant issues confronting the world now is climate change *(Rodríguez and Alsop 2016)*. It is creating abrupt and extreme changes *(Arshad et al. 2018)*, affecting all societies (Heininen 2022), and endangering human life (*Arshad et al. 2018*). According to *Ara Parvin and Reazul Ahsan (2013),* the effects of climate change are more acute and intense in marginalized and impoverished groups, and many Indigenous communities are among the most at risk *(Leal Filho et al. 2021)*. Indigenous communities mainly rely on their Indigenous Knowledge (IK) systems to improve adaptation and resilience to the multifaceted changes brought about by climate change *(Apraku et al. 2018)*. IK stands for Indigenous knowledge, customs, beliefs, and insights that have been accumulated over many centuries *(Sukula 2006)*. Climate change poses a significant threat to agricultural productivity and food security worldwide. ITK can play a pivotal role in helping communities adapt to changing environmental conditions. Indigenous farmers often have an intimate understanding of local weather patterns and ecological changes, allowing them to predict seasonal shifts and adapt their agricultural practices accordingly. This includes selecting drought-resistant crop varieties, adjusting planting schedules, and utilizing water conservation techniques that have been honed over generations. Indigenous knowledge of plant biodiversity, for instance, is crucial for identifying crop varieties that are more resilient to climate extremes such as heatwaves, floods, or droughts. Climate resilient agriculture can offer a viable route that can enhance resilience, productivity, and carbon sequestration by fusing ancient knowledge with contemporary methods (*Birthal et al., 2021; Singha et al., 2024; Angom & Viswanathan, 2023*; *Goswami et al., 2023; Shiiba, 2022*). Case studies from throughout the world show how effective the Climate resilient agriculture is in enhancing water management and food security. In South Korea, for instance, *Kim et al. (2020)* used generalized linear models (GLMs) to investigate how land cover affects flooding, highlighting the significance of farmer-maintained irrigation systems based on ecological knowledge from traditional sources. Similarly, *Shahzad et al. (2021*) investigated the production of stress-responsive plant transcription factors for growing climate-resilient crops globally, while *Ha et al. (2020)* used dynamic modeling to evaluate climate-resilient livelihoods for smallholder farmers in Vietnam.

4. Pest and Disease Management

Traditional pest management techniques are often more environmentally sustainable than modern chemical-based approaches. ITK includes the use of natural pest repellents, intercropping, crop rotation, and the promotion of beneficial organisms like predatory insects and birds. Farmers from all around the region have created their own agricultural methods for growing a variety of crops. Indigenous technological knowledge (ITK) is the term used to describe these processes *(Deka et al., 2006)*. In the areas of agriculture, fisheries, health, livestock, and forestry, ITKs maximize local thinking and are pragmatic by nature (*Charyulu, 2007)*. According to *Berkes et al. (2000),* agricultural scientists thought that ITKs could be very helpful in resolving problems pertaining to contemporary agriculture and the environment. In order to preserve the viability of the seeds, farmers frequently store rice seeds in containers with multiple layers of paddy straw *(Verma et.al.1999)*. Similar to this, in the rain-fed uplands of Orissa's mid-central zone, farmers utilize a thin wooden country plough to do one cross ploughing (Mendha) three days after planting paddy, followed by laddering (Garamai) three days later *(Sahoo et.al, 2002*). Once more, following three days of garamai, use a tooth harrow (Bida) to control weeds, soil compaction, and moisture conservation as well it

helps in tillering, it also destroys the white ants and ultimately maximizes the yield(*Sahoo et.al, 2002)*. According to *Fraser et al. (2006*), Indigenous knowledge has occasionally also aided conservation planning. Cultural customs aid in the control, suppression, or elimination of the pest population. Here are a few examples of cultural customs that have been adopted in different parts of India. For instance, Using castor as a trap crop in cotton helps to avoid insect attacks on the primary crop, and because of the higher predator density, the production of intercrops such cow pea, greengram, and blackgram lowers the amount of sucking pests like aphids, leaf hoppers, and boll worms *(Gohain et al., 2019)*.For generations, using neem leaves in storage bags as a means of preventing damage by pests has been employed by farmers in India. It is observed that farmers of West Bengal, Bihar, Andhra Pradesh and Tamil Nadu used it to protect paddy, and those in Madhya Pradesh, Uttar Pradesh, Haryana, Punjab and Maharashtra to protect wheat *(Samanta, R.K., Prasad, M.V., 1995)*

The evaluation of ITKs is a necessary component of introducing new agricultural technology, according to the scientific community. It is acknowledged that before developing and distributing any new technology, farmers' expertise must be considered.These practices help maintain pest populations at levels that do not harm crop yields, thus reducing the need for chemical pesticides that can harm ecosystems and human health. Indigenous knowledge of natural predators and biological control systems is vital in maintaining balanced ecosystems while supporting food production.

ITK and Livelihood Security

1. Food Security

In order to ensure that the needs of the present are satisfied without jeopardizing the ability of future generations to meet their own needs, sustainable development aims to achieve a balance between economic growth, environmental protection, and social equity" *(Brundtland, 1987)*.ITK plays a crucial role in ensuring food security in rural communities, especially in areas where access to modern agricultural inputs or technologies may be limited. By using indigenous seeds and farming techniques, communities can produce a diverse range of crops suited to local conditions, which ensures a stable and nutritious food supply. Additionally, many ITK practices focus on preserving local knowledge of wild foods, which can provide supplementary nutrition in times of crop failure or food scarcity.For example thefarmers in semi-arid regions of upper-eastern Kenya have embraced drought-tolerant crops like millet and sorghum to reduce food insecurity *(Umesh et al., 2015)*. While the excess is sold to generate revenue, sorghum and millet are consumed locally. Unfortunately, because of the frequent, prolonged dry seasons and droughts that occur in drier agroecologies, the promise of these drought-tolerant traditional food crops has not yet been completely realized (*Mwadalu and Mwangi, 2013)*. According to *Evans and Sadler (2008),* it is crucial to effectively catch and utilize the little amount of water that is accessible in arid and semi-arid regions. By optimizing the amount of moisture accessible through water collection in farming systems, small-scale farmers can improve their lives and ensure food and financial security*(Nicol et al., 2015)*.

2. Cultural Preservation and Community Empowerment

Traditional ecological knowledge is being lost in tandem with the acceleration of language loss and the deterioration of traditional livelihoods reliant on natural resources *(Loh and Harmon 2014)*. Indigenous communities and humanity at large may find it more difficult to obtain a comprehensive understanding and management framework for dealing with endangered species, habitats, and the stresses currently placed on them as a result of this compromised knowledge base, which is demonstrated by the misuse of terms that refer to specific organisms or ecological interactions

(Berkes 2012). Furthermore, the distribution of speakers and languages around the world is becoming more and more lopsided. The distributions, ecological requirements, and behavior of endemic or locally decreasing species, however, may nevertheless be better understood by local or indigenous peoples than by scientists with Western training *(Nabhan 2000).* We desperately need this kind of place-based knowledge to direct efforts at habitat restoration and species recovery. Additionally, according to *Berkes (2012),* these initiatives might be crucial to preserving the resources that indigenous hunters, foragers, and fishers depend on for their livelihoods. The biocultural diversity that remains in First Nations lands and waters has thankfully been documented for decades by researchers in the biological and social sciences working with indigenous leaders *(Maffi 2001*). Up until recently, professional scientists provided technical support for studies, whereas traditional tribe elders formally oversaw or directed just a small percentage of them (*Gupta et al. 1993*).

ITK is closely tied to the cultural heritage and identity of indigenous communities. It supports community cohesion and the preservation of traditional values, knowledge systems, and practices. In addition to its agricultural benefits, ITK contributes to the social fabric by promoting community-based resource management, collective decision-making, and intergenerational knowledge transmission. Empowering indigenous communities to manage their natural resources and agricultural systems leads to improved governance and increased social resilience.

Challenges to the Integration of ITK

1. Loss of Traditional Knowledge

The erosion of indigenous cultures and the loss of traditional knowledge due to globalization, urbanization, and the dominance of industrial agriculture pose significant challenges. But according to *Loh and Harmon (2014)*, adaptive ecological knowledge is fast changing, if not completely disappearing.Particularly in communities that are impacted by the decreasing usage of their native tongues. Communities trying to preserve their traditional means of subsistence based on local natural resources and revive their native tongues must thus be given immediate help. Fortunately, initiatives to include indigenous cultures in programs that revive forgotten customs and knowledge and restore the habitats of endangered animals are becoming more and more prevalent. Examples include the extensive monitoring of carbon stocks and wildlife populations in Amazonia by indigenous people *(Luzar et al. 2011 and Butt et al. 2015)*, as well as the mapping of traditional lands in the little-known Darién province of Panama *(Herlihy 2003).*

Younger generations may be less interested in maintaining traditional practices, and many indigenous languages, which carry much of the agricultural knowledge, are at risk of disappearing.

2. Recognition and Valuation

Indigenous knowledge is often marginalized within formal scientific and policy frameworks, which prioritize modern technologies and methods. We observe that there is no universal meaning of the term Indigenous, and that the term is frequently - but not always - employed to comprehend the historical and contemporary repercussions of colonial processes *(Arvin, 2015).* In this analysis, we connect the word Indigenous with the framework of the United Nations Declaration on the Rights of Indigenous Peoples *(UN, 2007).* We define Indigenous peoples as those who inherit and practice unique cultures, knowledge, and ways of relating to the environment, have ancestral ties to their territories, and frequently have languages and sociopolitical systems that differ from those of the dominant societies in which they live. Indigenous peoples are projected to number between 375 and 500 million globally (*UNDP, 2019).*While Indigenous peoples account

for only five to six percent of the worldwide population, they officially own 18 percent of the world's land and claim much more *(UNEP, 2017)*. Traditional Indigenous territories cover 80 percent of the planet's terrestrial biodiversity *(Sobrevila, 2008)*.

This knowledge has been inherited from preceding generation, with each new generation making continual adjustments to adapt to evolving circumstances and environmental factors and inturn pass down this wealth of knowledge to the succeeding generation as a means of survival strategies *(Donato-Kinomis,2016)* here is a need for greater recognition and valuation of ITK within national and international agricultural policies. This involves not only acknowledging the technical expertise of indigenous communities but also understanding the cultural, spiritual, and ecological dimensions of their knowledge systems.

3. Intellectual Property Issues

The use of ITK in modern agricultural systems raises important issues related to intellectual property rights and the protection of indigenous knowledge from exploitation. There is a need for frameworks that ensure fair compensation and recognition for indigenous communities whose knowledge contributes to scientific and agricultural advancements.For example in the late 1990s, the USPTO (United States Patent & Trademark Office) granted a patent on the wound healing properties of turmeric and basmati rice, while the European Patent Office granted a patent on neem-based bio-pesticide. These incidents highlighted the necessity to safeguard ITKs. Following these incidents, India initiated the scouting and documentation of ITKs in the Traditional Knowledge Digital Library (TKDL). International laws and treaties, such as the Convention on Biological Diversity (1992) and Nagoya Protocol (2010), promote benefit sharing, but do not recognize rights to previously published traditional knowledge in the public domain. Also, the community must rely on users to reap benefits. The progress of GIs registration in India shows the government and voluntary organisations interest to promote and protect the region cultural as well as biological diversity *(Kumar and Srivastava, 2017).Gupta (1993)* suggests that IPR arguments should focus on the "tradition of invention" rather than "inventing a tradition" to enhance its function in disseminating traditional knowledge. According to *Farnsworth (1981*), 80 percent of modern plant-based medications are utilized for the same purpose that primitive people found. In investigations conducted in Nigeria, the correlation between claims made by local people and data from current pharmaceutical research was greater than 85% (*Iwu, 1996)*. In 1996, Chinese patent holders accounted for 45% of all herbal-based patents, followed by Japan (22%), and Russia (*16.5%) (Gupta, 1999)*.

Therefore, in order to create strategic programs for sustainable agriculture and to start the patenting process, it is necessary to methodically document, validate, and incorporate indigenous techniques into the scientific process.

4. Policy and Institutional Support

The categories frequently overlap, but in all cases, local knowledge is the primary resource that is controlled by at least some of the 'country people', whilst lands, natural resources, and labor have been stolen by outside powers *(Mc Call, M.K., 1995)*.

Integrating ITK into mainstream agricultural policies and practices requires supportive policies and institutional frameworks. This includes creating spaces for dialogue between indigenous knowledge holders, researchers, policymakers, and agricultural practitioners. Such integration can be facilitated through participatory research, co-management initiatives, and the development of community-based resource management programs.Indigenous knowledge of ecological zones, natural resources, agriculture, aquaculture, forests, and game management frequently outstrips current understanding in terms of its breadth and relevance, according to *(Posey, 1995)*. Integrating IK with

modern scientific methods improves ecological resilience. It is crucial to respect and incorporate indigenous knowledge into national and international development policies in order to produce more sustainable and culturally relevant results *(Eyford, 1990)*.

Pathways for Revitalizing and Mainstreaming ITK

1. **Documentation and Codification:** Efforts to document and codify indigenous knowledge should be prioritized, not only for preservation but also to facilitate its integration into modern agricultural systems. This should be done in collaboration with indigenous communities, respecting their intellectual property rights and ensuring that they benefit from the sharing of their knowledge.
2. **Research and Collaboration**: Collaboration between indigenous knowledge holders and academic researchers can lead to the development of hybrid agricultural systems that combine the strengths of both traditional and modern practices. Research institutions should engage with indigenous communities to co-develop solutions to contemporary agricultural challenges.
3. **Policy Reforms**: Governments should create policies that support the integration of ITK into national agricultural strategies, ensuring that indigenous communities are included in decision-making processes and benefit from agricultural development programs.
4. **Education and Capacity Building:** Programs to promote ITK among younger generations and incorporate it into formal education systems can help revitalize these practices. Training programs for farmers, extension workers, and policymakers on the benefits and applications of ITK can facilitate its wider adoption.

More specifically it can bedescribedthat how local taxonomies and Western knowledge schemes converge and congruence, as well as how they differ or are inconsistent with the Western scientific classification system. There is a dire need of involvement of local or indigenous groups in biodiversity documentation and management through intergenerational learning that is culture-driven, employing methods based on native languages and other ecological knowledge instruments and techniques. As a way to preserve or revive indigenous knowledge and practices and promote traditional livelihoods, empower and assist indigenous or local groups who decide to create their own programs for managing and recovering endangered species in their lands and waterways.

CONCLUSION

Indigenous Technical Knowledge offers a wealth of insights and practices that can significantly contribute to sustainable agriculture and livelihood security. By fostering biodiversity, enhancing climate resilience, and promoting ecological balance, ITK offers a holistic approach to agriculture that complements and enhances modern farming techniques. Among indigenous civilizations around the world there are many subtleties of local classification systems represent a wealth of knowledge developed over the millennia, the breadth and depth of which are progressively shrinking. We run the risk of our institutions overlooking the chance for consilience among the many sources of information if we do not adequately recognize the actual and potential worth of indigenous technical knowledge and its science as it does professional academic and citizen science. We must pursue information that can improve our response to a world in poverty because the difficulties we confront as a species and as nations, societies, communities, and individuals are too tremendous to ignore.However, to fully realize its potential, there must be concerted efforts to protect,

document, and integrate ITK into contemporary agricultural policies and practices. Doing so will not only improve agricultural sustainability but also empower indigenous communities, helping to secure their livelihoods and cultural heritage for future generations.

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IMPORTANCE OF ARBUSCULAR MYCORRHIZA (AM) FUNGI IN AGRICULTURE

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ABSTRACT

AM fungi are symbiotic association.It is an obligate relationship for the fungi.It is observed that 80-90 percent of flowering plants are mycorrhizal. AM fungi very beneficial for the growth and development of plants. It helps plants to survive stress condition like salinity, drought, heavy metal contaminated soil. AMF helps in the uptake of soil nutrients especially N and P, which is very helpful for promoting the growth of host plants. They improve the soil aggregation which in turn enhances the quality and texture of soil and helps in soil and water conservation.

Keywords: *AM fungi, drought, growth, nutrients, soil, water conservation*

INTRODUCTION

AMF are obligate symbionts belonging to phylum Glomeromycota whichform symbiotic associations with a diverse range of plants (Schussler *et al*., 2001).They are involved with about more than 80% of the plant species. However, families- Brassicacea and Chenopodiaceae do not show mycorrhizal associations (Newman and Reddell, 1987).AMF are soil- borne microorganisms. The fungal hyphae colonize the cortical cells of the roots of plants. There are several types of fungi which form such associations with plants but the most useful and important ones amongst them are the AMF. The positive effects of AMF inoculation include- production of phytohormones and secondary metabolic products- vitamins, amino acids, etc. They help the plants fight abiotic stresses such as excessive heat and drought (Auge´ *et al*., 1994) and make them disease tolerant. They stimulate better uptake and absorption of macronutrients like Phosphorus, Nitrogen, Magnesium and Potassium (Smith and Read, 1997; Clark and Zeto, 2000; Hodge *et al*.,2001) and micronutrients Copper and Zinc (Gildon and Tinker, 1983; Faber *et al*., 1990; Kothari *et al*., 1991a; Li *et al.,* 1991; Azaizeh*et al*., 1995).They also bind the soil well together increasing their water retaining capacity.

AMF form arbuscles, vesicles and hyphae in roots and spores and hyphae in rhizosphere. The hyphal network formed by AMF increases the surface area of soil for absorption of nutrition thus, promoting plant growth (Bowles et al., 2016).

AMF are also known to relieve the toxicity of heavy metals in host plants and to tolerate high levels of metals in soil(Göhre and Paszkowski, 2006; Lingua et al., 2008;

Cornejo et al., 2013; Tamayo et al., 2014; Meier et al., 2015).

AMF have an impact on the ecosystem as well. They improve the soil aggregation (Rillig and Mummey, 2006; Leifheitet al., 2014, 2015; Rilliget al., 2015)which in turn enhances the quality and texture of soil and helps in soil and water conservation. Some recent investigations have been made regarding the influence of AM symbiosis on the emission of greenhouse gases (Bender et al., 2014; Lazcanoet al., 2014).

Bender et al. (2014) illustrated that AMF also contribute in reducing the N_2O emissions hence, playing an important role in reducing the level of greenhouse gases and thereby keeping a check on the climate.

AMF as bio-fertilizers

Bio-fertilizers are substances that contain microorganisms, which when added to soil increase its fertility and promote plant growth. They are considered as bio-fertilizers because they provide the host plant beneficial nutrients, water and protection from harmful pathogen, in exchange for photosynthetic products (Smith and Read, 2008). It is therefore considered that inorganic fertilizers could be replaced with AMF in the coming years, which would prove beneficial not only to the plants but also to the environment. Extensive use of chemical fertilizers, herbicides and insecticides cause major health, soil and plant problems. They further damage the quality of food products; disturb the soil and water systems.The capability of AMF as bio-fertilizers was explored by McGonigle (1988), Lekberg and Koide (2005), and Berrutiet al. (2016) .The use AMF as bio-fertilizers in sustainable crop productivity is encouraged by the researchers (Barrow, 2012). It is assumed that the use of AMF can lower the use of chemical fertilizers possibly by 50%, but this estimate also varies from plant to plant and the type of abiotic stress.

AMF and Mineral Nutrition

Inoculation of nutritive agents such as AMF help in increasing the efficiency of both nutrient usage as well as absorption by plants. AMF colonization is assumed to stimulate the uptake of nutrients in plants. It stimulates the mineral solubilization and water absorption efficiency(Nadeem *et al*., 2017). It is noticeable that injecting AMF can enhance the concentration of several macronutrients and micronutrients, which leads to an increase in the photosynthesis and hence increases the production (Chen et al., 2017; Mitra et al., 2019)AMF specifically enhance the uptake of Phosphates from the soil(Smith et al., 2003; Nell et al., 2010). AMF are known to improve the surface-absorbing ability of host roots(Bisleski, 1973). A symbiotic relationship develops between AMF and the roots wherein the AMF help the absorption of essential nutrients from host plant and in return provides mineral nutrients like N, P, K, Ca, Zn and S. Hence, AMF provides nutritional support to plants even under stress conditions. AMF form special structures called arbuscles which promote the exchange between inorganic minerals and compounds of C and P,thus imparting strength to host plants(Li et al., 2016b; Prasad et al., 2017).Liu et al., 2014; Liu et al., 2018reported that AMF association very helpfulto uptake of P and N thereby helping in plant development at higher and lower P levels under different irrigation routines. For example, inoculation of AMF in plant tissues of *Chrysanthemum morifolium* improved its P and N contents(Wang et al., 2018) and increased the seedling weight by improving

water content and intercellular CO_2, N and P contents in *Leymus chinensis*(Jixianget al., 2017).

Nitrogen is not only a main source of soil nutrition but also a well-known mineral fertilizer. AMF helps in the uptake of soil nutrients especially N and P, which is effective in promoting the growth of host plants(Smith et al., 2011). Many studies have shown that AMF have the ability to absorb N and transfer it to its neighboring plants(Hodge and Storer, 2015; Battiniet al., 2017; Turriniet al., 2018). AMF association valuable to maintain the Nitrogen (N) & Phosphorus (P) concentration,the interaction between AMF and the salinity stress remarkably affects the concentrations of Phosphorus (P) and Nitrogen (N) and also the N:P ratio in plant shoots(Wang et al., 2018)

It is widely acknowledged that fungi are able to take considerable amount of N from the dead and decaying material. The extra-radical hyphae of AMF help in absorbing and assimilating inorganic N(Jinet al., 2005).An increase in the amount of N in AMF-colonized plants shows increase chlorophyll levels and chlorophyll molecules can effectively capture Nitrogen (N)(De Andrade et al., 2015).

AMF and Plant Yield

Currently in many parts of the world, the increased crop yield is due to excessive use of chemical fertilizers(Ju *et al*. 2009)

Soil organisms perform most of the nutrient alterations in soil. They play a major role in driving the nutrient cycle through their activities and determine whether the nutrients are available to plants, are stored in the soil or are on the verge of being lost from plant-soil system(Robertson &Groffman 2007; van der Heijden, Bardgett& van Straalen 2008).

Apart from enhancing the nutritional status of plants, the beneficial microorganisms of rhizosphere also help improve the quality of crops.

Baslamet al., 2011reported that mycorrhizal associations enhanced the accumulation of several mineral nutrients, chlorophyll, carotenoids, anthocyanins and tocopherols. AMF have been employed for large-scale production of potato(Hijri, 2016) and maize(Sabia et al., 2015).

AMF and Abiotic Stresses

AMF also helps in improving the resistance of plants to stressful environments.

Drought

Drought triggers a wide variety of plant responses. It effects several plant phenomena such as enzymatic activity, ion uptake and nutrient assimilation thus imparting destructive effects to plants(Ahanger and Agarwal, 2017; Ahanger et al., 2017a). However, there are evidences in support of drought stress alleviation by AMF in various crops like wheat, barley, strawberry, soybean, onion and maize(Mena-Violanteet al., 2006; Ruiz-Lozano et al., 2015; Yooyongwechet al., 2016; Moradtalabet al., 2019). The increased tolerance levels of plants to drought could be due to larger surface area of soil being explored by roots and the hyphae of AMF(Gianinazziet al., 2010; Orfanoudakiset al., 2010; Gutjahr&Paszkowski, 2013; Zhang et al., 2016).

Salinity

Soil salinization affects the production of crops by interfering with the nitrogen uptake, reducing plant growth and inhibition of plant reproduction. It boosts excessive generation of reactive oxygen species(Ahmad et al., 2010; Ahanger and Agarwal, 2017; Ahangeret al., 2017b; Ahangeret al., 2018).AMF association promotethe growth and yield in plants under salinity stress(Talaat

and Shawky, 2014; Abdel Latef and Chaoxing, 2014)

Ait-El-Mokhtar et al. (2019)recently reported that AMF associations have favourable effects on the physiological parameters of plants such as the stomatal opening and closing, photosynthetic rate etc. Also lately Wang et al. (2018) reported that there is some amount of increase in the N concentration of shoot and root and fresh and dry weights due to mycorrhizal symbiosis under average saline stress.

Plants possessing AMF have also shown increase in production levels of jasmonates and salicylates. For instance, the AMF-inoculated *Cucumis sativus* plants showed higher concentrations of minerals like P, Ca^{2+}, Mg^{2+}, N and K when compared with those of untreated plants under salt stress(Hashem et al., 2018).

Heavy Metals

Essential and non-essential heavy metals produce toxic effects on plants like chlorosis, inhibition of growth and photosynthesis, altered water balance and nutrient assimilation etc. which ultimately leads to the death of the plants. AMF associations help strengthen the defense system of metal contaminated plants thus promoting their growth and development. Heavy metals cause various health hazards due to their accumulation in various food crops, fruits, vegetables and soil(Liu et al., 2013; Yousaf et al., 2016)

Temperature (Low and High)

Heat stress severely affects the plant growth and yields loss of plant vigour and inhibitseed germination and also decreased biomass production.This association also responsible for damage and discolouration of fruit and reduction in yield and cell death(Wahid et al., 2007; Hasanuzzamanet al., 2013) Usually, AMF-inoculated plants show better growth and development under heat stress as compared to the non-AMF-inoculated ones(Gavitoet al., 2005)

AMF association also help the plants to survivein cold stress(Birhaneet al., 2012; Chen et al., 2013; Liu et al., 2013).AMF symbiosis promote the synthesis of chlorophyll which help the plants to survive under cold stress conditions(Zhu et al., 2010a; Abdel Latef&Chaoxing, 2011b).

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CHECKING HEALTH STATUS OF THE SOIL PROFILE USING NEMATODE INDICATORS FOR SUSTAINABLE LIVELIHOOD

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ABSTRACT

Soil health is crucial to sustainable agriculture and food security because it supports resilient livelihoods and ecosystem services. Nematodes are small, functionally diverse soil organisms that serve as unique bioindicators due to their sensitivity to pollutants and disturbances. Traditional soil assessments incorporate physical, chemical, and biological measurements. To demonstrate how nematode communities, reflect soil conditions, guide management, and promote sustainable lifestyles, the paper examines the principles, evaluation techniques, and real-world applications of nematode-based monitoring.

Keywords : *Soil health, bio-indicators, nematodes,sustainable agriculture, ecological indicators.*

INTRODUCTION

Soil health is a fundamental component of sustainable agriculture, environmental stability, and food security. (Lu, 2020; Athar and Kanwal, 2022). The idea is not just about agricultural productivity; it also encompasses the soil's ability to act as a living system that supports the growth of plants and animals, keeps water and air clean, and keeps plants, animals, and people healthy. (Fausak, 2024; Mosaic, 2024). Healthy soils are dynamic ecosystems that contain microbes, invertebrates, and organic matter that help with nutrient cycling, structural stability, and natural disease control. (Athar and Kanwal, 2022; Plantwise, 2025).

More than 99 percent of the food consumed globally derives from soil, which makes its conservation crucial for long-term food security (Mosaic, 2024). Soil also provides essential ecosystem services such as water filtering, nutrient availability, and greenhouse-gas management through carbon sequestration (Plantwise, 2025; Fausak, 2024). Its biological component, especially the diversity and quantity of organisms including bacteria, fungus, nematodes, and earthworms, works as a sensitive indicator of soil quality.High biodiversity enables agroecosystems resistant to pests, disease outbreaks, and climate change (Lu, 2020; Plantwise, 2025).

Unsustainable practices including excessive cultivation, extensive chemical fertilizer use, monocropping, and inadequate organic matter management continue to deteriorate soil health. These methods increase erosion by decreasing soil fertility, nutrient availability, water retention, and structural integrity (Athar and Kanwal, 2022; Plantwise, 2025; Fausak, 2024). The livelihoods of

farming communities and future agricultural productivity are at risk due to the approximately 30% of land that is currently degraded worldwide. Low levels of organic carbon and nutrient imbalances have led to lower crop yields and financial losses in India. (Mosaic, 2024).

In order to restore and maintain soil health, there is an increasing focus on integrated, conservation-oriented soil management techniques such crop rotation, organic fertilization, decreased cultivation, cover crops, and biofertilizer use (Athar &Kanwal, 2022; Fausak, 2024; Mosaic, 2024). These methods boost the agroecosystem's resistance to harsh weather conditions, increase soil organic matter retention, strengthen the composition of the soil, and increase microbial and ecological biodiversity. The move toward agroecological and regenerative systems strengthens the connection between soil health and more general environmental and socioeconomic consequences, such as rural development and climate change mitigation. (Fausak, 2024; Plantwise, 2025).

Reliable indicators are crucial in this situation for tracking soil health and directing management choices. Biological evaluation, particularly the use of nematodes as sensitive bioindicators, is developing as a viable approach for evaluating soil sustainability by providing practical insights into the productivity, resilience, and multifunctionality required for sustainable development (Lu, 2020).

The Role of Nematodes in Soil Ecosystem

Nematodes comprise a variety of functional groupings, such as fungivores, omnivores, free-living bacterivores, plant-parasitic forms, and entomopathogenic species (Devi, 2024; Neher, 2001). Free-living nematodes play a crucial role in nutrient cycling and organic matter decomposition, whereas predatory varieties regulate soil food web dynamics and assist in insect population suppression (Neher, 2001; Lu, 2020). Their abundance, diversity, and community composition reflect essential soil processes such as organic matter turnover, mineralization, and nutrient availability, making them useful markers of environmental change (Lu, 2020). In contrast, a rise in plant-parasitic nematodes frequently indicates soil degradation caused by inadequate management or excessive chemical inputs (Lu, 2020; Devi, 2024).

Methodology

Soil health is assessed using nematodes in a systematic manner that includes field sampling, laboratory extraction, identification, and ecological index computation to create valid bioindicators of soil quality and ecosystem functioning (Lu, 2020; Devi, 2024). The major steps in the methodology are as follows:

Soil Sampling

To capture regional diversity within the soil profile, soil samples are taken from the study site at several locations and depths (Makeleni, 2025). Nematode activity typically occurs within the upper 0–20 cm of the soil profile; hence, sampling is largely focused at this depth. To ensure a representative recovery of nematode populations, soil samples are taken using digging instruments or soil cores.To maintain nematode viability prior to analysis, collected samples are maintained under cool and moist conditions until analysis (Lu, 2020).

Nematode Extraction

For nematode extraction, soil samples are processed using standard procedures, including the Baermann funnel method and centrifugal flotation. These widely known procedures provide efficient separation of nematodes from soil particles and related organic waste, ensuring dependable recovery for further investigation (Devi, 2024; Makeleni, 2025). Extraction generally takes 24–48 hours to ensure recovery of active and live nematodes.

Identification and Enumeration

Nematodes are identified under a light microscope, usually to the genus or species level,

using established morphological keys (Lu, 2020). Identification allows them to be classified into functional groupings or trophic guilds, which include bacterivores, fungivores, plant-parasitic nematodes, omnivores, and predators (Devi, 2024; Neher, 2001). Nematode enumeration in subsamples offers population density data, which is critical for studying community structure and ecological function.

Ecological Indices Calculation

Quantitative ecological indicators are utilized to turn nematode community data into usable soil health metrics(Ghaderi et al., 2025):

Index Name	What It Indicates	Ecological Interpretation
Maturity Index (MI)	Level of soil disturbance (colonizer vs. persister nematodes)	Lower MI suggests disturbance; higher MI reflects stable, undisturbed soils.
Enrichment Index (EI)	Available resources and nutrient enrichment	High EI implies recent resource input or organic matter enrichment.
Structure Index (SI)	Complexity and connectivity of soil food webs	High SI denotes a structured, complex food web; low SI indicates simplification.
Basal Index (BI)	Stress or degradation (dominance of stress-tolerant nematodes)	High BI shows stress conditions or resource limitation.
Channel Index (CI)	Predominant decomposition pathway (bacterial vs. fungal)	High CI indicates fungal pathway dominance; low CI indicates bacterial pathways.

Maturity Index (MI): Shows the degree of soil disturbance based on the ratio of colonizer to persistent nematodes.

Enrichment Index (EI): Reflects available resources and nutrient enrichment.

Structure Index (SI): Measures the complexity and connectivity of soil food webs.

Basal Index (BI): Indicates degradation or stress when stress-tolerant nematodes predominate.

Channel Index (CI): Establishes the predominance of fungal or bacterial breakdown processes.

Furthermore, novel integrated indices, such as the Nematode Soil Health (NSH) Index, combine various biotic markers into a single value, making them more practical for field use (Ghaderi et al., 2025).

Molecular Techniques

Molecular techniques such as high-throughput sequencing (HTS) and metabarcoding have made it possible to quickly characterize nematode communities and identify cryptic species, which supports morphology-based identification (Blanco-Pérez et al., 2025). These instruments enhance nematode-based soil health assessment's precision and scalability, particularly in intricate or severely disrupted ecosystems.

Data Interpretation

Nematode community composition and associated indices are evaluated in connection to land use, management strategies, and environmental variables (Makeleni, 2025; Devi, 2024). In order to maintain sustainable soil function, adaptive management can be guided by changes in trophic groups or index values, which can reveal soil enrichment, disturbance, or degradation (Lu, 2020).

This methodology is based on nematode biology and ecology and provides an integrative, sensitive, and practical strategy for monitoring soil health in both agricultural and natural ecosystems.

Impact of Land Management and Environmental Change

Nematode community structure is heavily shaped by land use, cropping patterns, and management practices (Makeleni, 2025; Lu, 2020; Neher, 2001). Conservation strategies such as crop variation, organic cultivation, and decreased tillage encourage various nematode communities and help sustain healthy soil food webs (Lu, 2020; Neher, 2001). In

Table - 1 : Nematode-Based Soil Health Indices and Their Interpretation

Index Name	Typical Value Range	Interpretation	Soil Health Implication
Maturity Index (MI)	Low (<2), High (>4)	Low: disturbed; High: mature, stable	Higher values indicate less disturbance, better soil health (Ferris et al., 2001)
Enrichment Index (EI)	Low (<40), High(>60)	Low: resource -poor; High: nutrient enrichment	High EI indicates recent nutrient input, can suggest disturbance or enrichment (Du Preez et al., 2022)
Structure Index (SI)	Low (<30), High(>60)	Low: simplified food web; High: complex food web	High SI means a well -structured and resilient community (Ferris et al., 2001)
Basal Index (BI)	Low (<40), High(>60)	Low: nutrient rich; High: stressed	High BI suggests soil stressed or resource -limited (Ferris et al., 2001)
Channel Index (CI)	Low (<50)= bacterial; High(>50) = fungal	Indicates dominant decomposition pathway	Bacterial dominance suggests rapid nutrient cycling; fungal dominance suggests stable, undisturbed soil (Du Preez et al., 2022)

contrast, monoculture, excessive chemical usage, and frequent tillage minimize nematode communities, increase plant-parasitic groups, and signal deteriorating soil health (Makeleni, 2025; Lu, 2020). Nematode-based assessments offer practical data that may direct adaptive management and policy decisions (Neher, 2001).

Application in Sustainable Livelihoods Nematode assessments benefit sustainable livelihoods by:

Early Detection and Remediation: Community patterns and biotic measurements assist identify degradation of soil, toxicology, and pollutants at an early stage, allowing appropriate action to be taken. (Lu, 2020; Devi, 2024). · **Integrated Pest Management (IPM):**Entomopathogenic nematodes support natural pest management and help reduce dependence on agrochemicals (Devi, 2024). · **Adaptive Cropping and Management:**Nematode measurements assist sustain productivity and increase smallholder resilience by guiding decisions about crop selection, input utilization, and amendment techniques (Makeleni, 2025; Lu, 2020). · **Knowledge Transfer:** Incorporating nematode monitoring into community or extension programs improves awareness, promotes data-based decision-making, and supports long-term sustainability (Devi, 2024).

Case Studies

Intensive Monoculture and Fertilization

A long-term study of cucumber monoculture in Hungary found that nematode assemblages revealed considerable food chain reduction and an increase in stress-tolerant bacterivores after decades of intensive fertilizer farming. The adaptation of plant-parasitic nematodes revealed ecosystem degradation and prolonged stress, as reflected by nematode biotic indices (PMC, 2024).

Elevation Gradient Community Structure

Nematode surveys and food web indices in Himalayan mountain regions found that diversity and functional complexity were linked to environmental variability. Valley areas had more species diversity, but high-altitude sites had simpler food webs and more disturbance, demonstrating nematode sensitivity to soil and climate conditions (Nature Publishing Group, 2022). ·

Sustainable Management in China

Field studies in China revealed that organic systems have better nematode maturity indices and greater diversity than conventional systems. These

findings support the use of nematode strategies in adaptive soil management and long-term sustainability (Lu, 2020; Makeleni, 2025).

CONCLUSION

The importance of nematode community analysis as a thorough biological technique for assessing soil health in agricultural systems is highlighted by this work. It provides a sensitive and environmentally friendly method for assessing soil disturbance, resource availability, food web structure, and early signs of degradation through the application of indices such as the Maturity Index (MI), Enrichment Index (EI), Structure Index (SI), Basal Index (BI), and Channel Index (CI). These indicators provide value beyond normal physicochemical measures and serve as a basis for soil monitoring and restoration across a wide range of agroecosystems.Research from around the world demonstrates that nematode-based diagnostics may accurately monitor changes in soil ecosystem functioning caused by environmental constraints, land use patterns, and management strategies. Crop rotation, decreased tillage, organic cultivation, and integrated pest management all contribute to maintaining nematode diversity, maintaining healthy food webs, and ensuring agricultural production's long-term viability. In contrast, extensive monoculture and high chemical application reduce nematode communities, intensify disturbing signals, and reduce long-term soil fertility.The early warning capabilities of nematode indices allows for timely soil repair, encourages adaptive management, and assists small-scale farmers in maintaining soil health and productivity. Nematode-based assessments are getting more precise and adaptive as morphological and molecular techniques progress, making them more useful for real-time field monitoring. Integrating nematode indicators into soil health programs is a promising step toward environmental sustainability, food security, and improved livelihoods. Their widespread adoption in research and extension initiatives will encourage understanding soil maintenance and productive agroecosystems that are linked with long-term sustainable development objectives.

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EFFECT OF NITROGEN WITH SULPHUR ON GROWTH AND YIELD OF ONION *(ALLIUM CEPA L.)* CV. ARKA NIKETAN

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ABSTRACT

The present study was conducted at the Kulbhaskar Ashram Post Graduate College, Prayagraj during rabi season of the year 2024-25. Plant material consisted of 10 treatments of Onion in randomized block design of 20 x 10 cm spacing with three replications. Evaluation was done for Effect of Nitrogen with Sulphur on growth and yield of onion *(Allium cepa L.)* cv. Arka Niketan. In results treatment T8 (N3S1) showed superior result for Plant Height (cm) (41.23,51.56,64.33,62.31), Number of leaves plant-1 (8.96, 10.33, 10.92, 10.45), Diameter of stem (cm) (1.866, 2.678, 3.125, 3.598), Fresh weight of top (gm) (28.62, 31.25, 33.45, 38.40,) , Fresh weight of bulb (gm)(23.19, 42.66, 49.98, 58.68), Fresh weight of Whole plant (gm)(51.72, 73.91, 83.43, 89.68), Diameter of bulb (cm) (3.99, 4.75) Dry weight of top (gm) (1.802, 2.295, 3.301, 2.744) Dry weight of bulb (gm)(8.67, 9.47, 9.66, 10.31) , Yield of bulb per plot (kg) (9.30), Yield of bulb(q/hac.) (251.28).

Keywords : *Onion, nitrogen, sulphur, growth, yield, arka niketan*

INTRODUCTION

Onion (Allium cepa L.) is the most important vegetable crop of the family alliacea. Chromosome number x=8 (2n=16).The primary centre of origin of onion in central Asia. The genus Allium having about 300 species. The type of inflorescence of onion is umbel. It is a tunicated bulb which develops in the soil. Grows as vegetables crops and is used for culinary purpose. It is an indispensable item in every kitchen vegetable and condiment used to flavor many at the stuffs. Therefore, onion is popularly known as „Queen of kitchen in addition onion is used as salad and pickles.

According to COMTRADE, United Nations -2022,Onion bulb is rich in minerals, especially calcium, potassium and phosphorus besides having fairly good quantities of carbohydrates, proteins and vitamins. The bulb is composed as chorbohydrates (11.0g) protein (1.2g) fiber (0.6g) moistures (86.8g) and energy (38 cal). Apart from these vitamins like vitamin C (11mg), thiamin (0.08mg), riboflavin (0.01mg) and niacin (0.02mg). Apart from these minerals like, phosphorus (39mg), calcium (27mg), sodium (1.0mg), iron (0.7mg), and potassium (1.57mg). The pungency in onion is due to the presence of volatile oil „allyl propyl disulfide (C6H12S2). The red color of onion bulb is due to the „anthocyanin . Studies showed that eating ((<200g of onion/week) result in less tendency to form blood clots and lower levels of cholesterol and lipoprotein associated with heart diseases in their blood serum than in abstainers.Although the nutritive value of onion is

low. It is greater valued for its inevitable and extensiveuses as a vegetables and medicine as well. It forms an indispensable parts of many diets of both vegetarian and non vegetarian as a flavoring agent. It is also consumed as salad regularly. Onion is sulphur rich compound as is also known to posses antibacterial properties.

Nitrogen is an essential element in all living systems and a major component of protein and chlorophyl. Under many agricultural setting, nitrogen is the limiting nutrient for high plant growth and yield (Marchner, 1995)

Sulphur is recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium in crops. Sulphur compounds, which give them their distinctive smell and pungency.

Sulphur plays critical roles in the catalytic or electrochemical functions of the bio-molecules in cells (Saito, 2004).

MATERIALS AND METHODS

The experiment was conducted at the farm of Department of Horticulture, Kulbhaskar Ashram Post Graduate College, Prayagraj, Uttar Pradesh during rabi season 2024-2025. The experiment was laid out with 10 treatments of Onion in randomized block design of 20x10cm2 spacing with three replications and the plot size it 2.6x1.5 m2.

Detail of treatments :

Sr. No.	Factors/Treatment	Treatment levels (kg/ha)	Notation
1.	Recommended dose of fertilizers	150:80:60 N:P:K	RDF
2.	Nitrogen	80	N_1
		100	N_2
		120	N_3
3.	Sulphur	0	S_0
		15	S_1
		20	S_2

Detail of treatment combinations :

Treatment/Notations	Treatment Combinations
To	RDF (Control)
T1	N_1So
T2	$N_1 S_1$
T3	N_1S_2
T4	N_2S_0
T5	N_2S_1
T6	N_2S_2
T7	N_3S_0
T8	N_3S_1
T9	N_3S_2

RESULT AND DISCUSSION

Plant height : The significantly maximum plant height in cm (41.23, 51.56, 64.33, 62.31) were recorded in treatment T8 (N3S1] at all DAT and at harvest), followed by T7 (N3S0) (40.00, 50.33, 62.00, 61.33) at all DAT and at harvesting respectively. The minimum plant height was observed in T0 RDF (Control) (28.65, 44.33, 53.25, 52.66) respectively.

Number of leaves per plant : The significantly maximum Number of leaves (8.96, 10.33, 10.92, 10.45) were recorded in treatment T8 (N3S1] at all DAT and at harvest), followed by T7 (N3S0) (40.00, 50.33, 62.00, 61.33) at all DAT and at harvesting respectively. The minimum plant height was observed in T0 RDF (Control) (7.12, 7.28, 8.01, 8.12) respectively.

Diameter of stem (cm): The significantly maximum diameter of stem (1.866, 2.678, 3.125, 3.598) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum plant height was observed in T0 RDF (Control) (1.468, 2.354, 2.698, 3.015) respectively.

Fresh weight of top (g): The significantly

maximum Fresh weight of top (28.62, 31.25, 33.45, 38.40) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum Fresh weight of top was observed in T0 RDF (Control) (20.10, 24.66, 27.80, 27.75) respectively.

Fresh weight of bulb (g): The significantly maximum Fresh weight of bulb (23.19, 42.66, 49.99, 58.68) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum Fresh weight of bulb was observed in T0 RDF (Control) (12.10, 22.54,30.67, 35.45) respectively.

Fresh weight of whole plant (g) : The significantly maximum Fresh weight of whole plant (51.72, 73.91, 83.43, 89.68) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum Fresh weight of whole plant was observed in T0 RDF (Control) (40.33, 51.64, 62.34, 72.33) respectively.

Diameter of bulb (cm) : The significantly maximum diameter of bulb (3.99, 4.75) were recorded in treatment T8 (N3S1] at all DAT and at

Table -1 : Effect of Nitrogen and Sulphur on plant height(cm) , number of leaves per plant, diameter of stem(cm), fresh weight of top(gm) at 30,60 90 and 120 DAT

	Plant height in cm				Number of leaves per plant				Diameter of stem in cm				Fresh weight of top (gm)			
Treatment	**30 DAT**	**60 DAT**	**90 DAT**	**120 DAT**	**30 DAT**	**60 DAT**	**90 DAT**	**120 DAT**	**30 DAT**	**60 DAT**	**90 DAT**	**120 DAT**	**30 DAT**	**60 DAT**	**90 DAT**	**120 DAT**
T_0	28.65	44.33	53.25	52.66	7.12	7.28	8.01	8.12	1.468	2.354	2.698	3.015	20.10	24.66	27.80	27.75
T_1	30.92	49.66	57.33	53.00	7.48	7.69	8.21	8.14	1.474	2.605	2.890	3.515	22.15	28.60	29.35	28.60
T_2	25.66	41.00	59.66	56.33	7.33	7.80	8.66	8.33	1.261	2.550	2.798	3.115	23.57	29.10	30.70	29.81
T_3	32.33	47.33	56.00	55.33	7.49	8.33	9.95	8.99	1.502	2.452	2.678	3.098	23.50	27.55	28.60	29.00
T_4	35.00	46.66	58.00	56.33	7.50	8.55	9.58	8.83	1.238	2.295	2.500	2.692	24.48	29.28	30.60	33.09
T_5	29.66	40.66	58.33	57.00	7.55	8.33	9.92	8.99	1.491	2.398	2.792	3.125	26.55	29.10	30.75	30.81
T_6	32.33	43.65	55.66	54.66	8.18	8.95	9.68	9.20	1.552	2.501	2.680	3.043	27.15	29.00	29.95	34.25
T_7	40.00	50.33	62.00	61.33	8.90	9.80	10.00	9.94	1.421	2.512	2.810	3.110	24.66	28.56	29.85	29.82
T_8	41.23	51.56	64.33	62.31	8.96	10.33	10.92	10.45	1.866	2.678	3.125	3.598	28.62	31.25	33.45	38.40
T_9	35.33	47.33	59.00	58.33	8.33	9.66	10.00	9.66	1.568	2.573	2.695	3.100	27.30	29.55	30.85	37.16
F test	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
SEm(±)	1.55	1.19	1.01	1.01	0.21	0.32	0.29	0.25	0.06	0.04	0.05	0.08	0.83	0.53	0.48	1.17
(CD) at 5%	0.77	0.60	0.50	0.51	0.10	0.16	0.14	0.12	0.03	0.02	0.3	0.04	0.41	0.27	0.24	0.59

harvest), respectively. The minimum diameter of bulb was observed in T0 RDF (Control) (2.29, 2.15) respectively. Dry weight of the top (gm) : The significantly maximum dry weight of top (1.802, 2.295, 3.301, 2.744) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum dry weight of top was observed in T0 RDF (Control) (1.210, 2.210, 2.242) respectively.

Dry weight of bulb (g) : The significantly maximum dry weight of bulb (8.67, 9.47, 9.66, 10.31) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum dry weight of bulb was observed in T0 RDF (Control) (4.30, 7.36, 7.69, 8.11) respectively.

Yield of bulb per plot (kg) : The significantly maximum yield of bulb (9.30) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum dry yield of bulb was observed in T0 RDF (Control) (8.40) respectively.

Yield of bulb (Q/ha) : The significantly maximum yield of bulb (251.28) were recorded in treatment T8 (N3S1] at all DAT and at harvest), respectively. The minimum dry yield of bulb was observed in T0 RDF (Control) (215.89) respectively.

Figure - 1 : Effect of Nitrogen and Sulphur on plant height(cm) , number of leaves per plant, diameter of stem(cm), fresh weight of top(gm) at 30,60, 90 and 120DAT

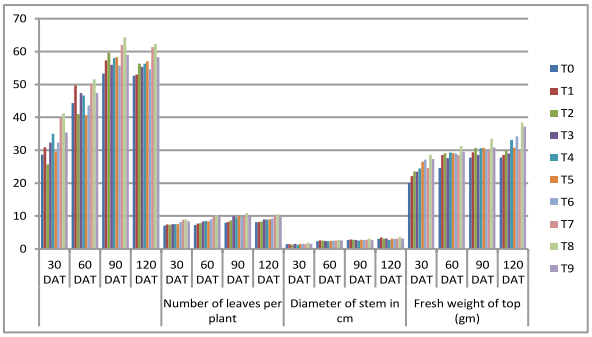

Table -2 : Effect of Nitrogen and Sulphur on fresh weight of bulb(gm), fresh weight of whole plant(gm), diameter of bulb(cm) at 90 and 120 DAT, dry weight of top(gm) at 30,60 ,90 and 120 DAT

Fresh weight of bulb in gm					Fresh weight of whole plant in gm				Diameter of bulb in cm		Dry weight of top in gm			
Treatment	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT
T_0	12.10	22.54	30.67	35.45	40.34	51.64	62.34	72.33	2.29	2.15	1.210	2.210	2.785	2.242
T_1	18.25	26.98	33.54	44.58	44.70	64.27	70.30	81.26	2.62	2.80	1.701	2.219	3.090	2.571
T_2	19.55	35.67	40.95	52.66	42.23	68.64	73.38	83.14	2.70	3.10	1.605	2.290	3.290	2.616
T_3	20.66	39.54	42.68	53.33	42.48	57.53	68.28	78.98	2.95	3.22	1.292	2.292	3.297	2.545
T_4	18.98	29.58	39.68	51.98	41.14	62.86	77.36	84.07	2.93	3.20	1.475	2.275	3.275	2.585
T_5	17.66	33.58	46.56	54.98	45.09	67.69	74.73	85.58	3.25	3.57	1.500	2.298	3.292	2.580
T_6	18.54	38.59	43.98	55.58	47.90	69.95	74.50	82.58	3.60	4.31	1.398	2.184	3.265	2.563
T_7	20.75	40.95	44.55	54.33	46.21	68.91	73.65	81.15	3.72	4.23	1.466	2.218	3.578	2.542
T_8	23.19	42.66	49.95	58.68	51.72	73.91	83.43	89.68	3.99	4.75	1.802	2.295	3.301	2.744
T_9	22.30	39.99	46.66	53.33	49.60	67.10	77.51	77.11	3.90	4.19	1.709	2.275	3.123	2.646
Ftest	S	S	S	S	S	S	S	S	S	S	S	S	S	S
(SEm ±)	0.97	2.12	1.90	2.00	1.19	2.06	1.81	1.50	0.19	0.25	0.06	0.01	0.06	0.04
(CD) at 5%	0.48	1.06	0.95	1.06	0.59	1.03	0.90	0.75	0.09	0.13	0.03	0.01	0.03	0.02

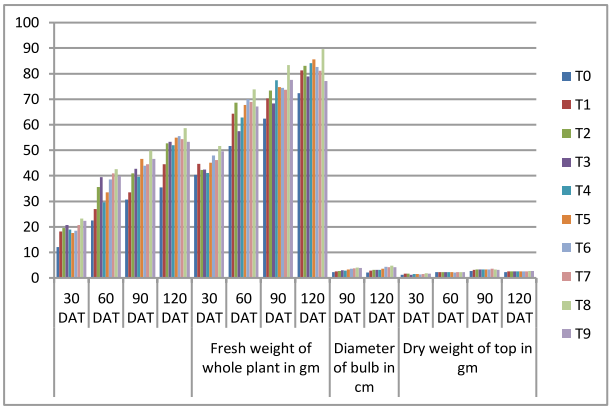

Figure - 2 : Effect of Nitrogen and Sulphur on fresh weight of bulb(gm), fresh weight of whole plant(gm), diameter of bulb(cm)90, 120 DAT, dry weight of top(gm) at 30,60, 90 and 120 DAT

Dry weight of bulb (g)

Yield of bulb per plot kg

Yield of bulb (q/hac).

CONCLUSION

All the treatment show significantly differences for most of the trait under study. The treatment T8 (N3S1 at 30 , 60, 90, 120 DAT), was found as the best treatment for majority of traits viz. Plant height (cm), Number of leaves per plant, Diameter of stem in cm, Fresh weight of top in gm, Fresh weight of bulb in gm, fresh weight of whole plant in gm, diameter of bulb in cm, dry weight of top in gm, dry weight of bulb in gm, yield of bulb per plot of kg, yield of bulb q/hac.

Table -3 : Effect of Nitrogen and Sulphur on dry weight of bulb(gm) at 30,60, 90, and 120 at DAT yield of bulb kg per plot, yield of bulb (q/hac.) at Harvesting.

Treatment	Dry weight of bulb (g)				Yield of bulb per plot kg	Yield of bulb (q/hac).
	30 DAT	60 DAT	90 DAT	120 DAT		
T_0	4.30	7.36	7.69	8.11	8.40	215.89
T_1	6.47	8.60	8.78	8.78	8.72	231.28
T_2	5.67	7.79	8.70	9.32	8.75	224.35
T_3	7.21	9.21	9.48	9.57	8.92	228.71
T_4	6.69	7.68	8.69	9.21	9.07	232.56
T_5	6.77	8.30	8.46	8.66	9.05	232.05
T_6	7.64	8.31	8.66	9.11	9.11	233.58
T_7	7.70	8.66	9.40	9.57	9.10	233.33
T_8	8.67	9.47	9.66	10.31	9.30	251.28
T_9	7.67	8.56	9.36	9.57	9.19	235.64
Ftest	S	S	S	S	S	S
(SEm ±)	0.39	0.21	0.19	0.19	0.08	2.83
(CD) at 5%	0.19	0.10	0.09	0.10	0.04	1.41

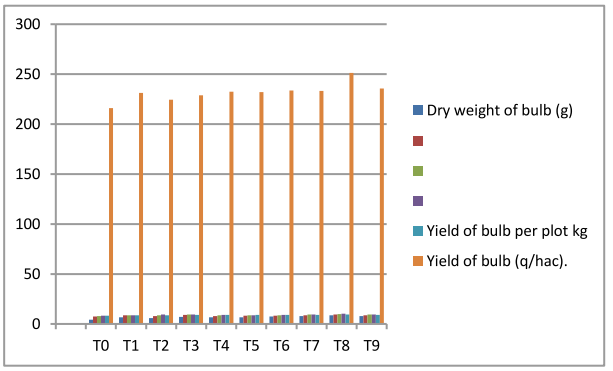

Figure -3 Effect of Nitrogen and Sulphur on dry weight of bulb(gm) at 30,60 ,90 and 120 DAT, yield of bulb kg per plot, yield of bulb (q/hac.) at Harvesting

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