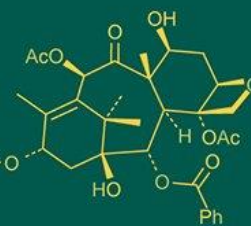
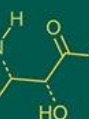
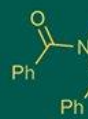


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Evaluation of eco-friendly and sustainable control measures against *Turcicum* leaf blight disease in maize cultivation

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Abstract

Turcicum leaf blight (TLB), caused by *Exserohilum turcicum* (Pass.) Leonard and Suggs, is one of the most destructive foliar diseases of maize (*Zea mays* L.), leading to significant yield losses and deterioration in grain quality worldwide. Excessive reliance on chemical fungicides for disease management raises concerns regarding environmental contamination, pathogen resistance, and adverse effects on beneficial microorganisms. Therefore, the present study aimed to evaluate eco-friendly and sustainable management approaches for controlling *Turcicum* leaf blight under field conditions. Various treatments comprising botanical extracts, bio-control agents, and organic amendments were assessed for their efficacy against disease incidence and severity. The experiment was conducted in a randomized block design with three replications. Disease severity, plant growth parameters, yield attributes, and grain yield were recorded and statistically analyzed. Among the tested treatments, *Trichoderma harzianum* combined with neem seed kernel extract exhibited the highest disease suppression and significantly enhanced plant growth and yield compared with untreated control. Bio-control agents and botanical formulations proved effective in reducing disease incidence while maintaining environmental sustainability. The results suggest that integrated eco-friendly approaches offer a promising alternative to synthetic fungicides for sustainable maize production and can be incorporated into integrated disease management programs.

Keywords: Maize, *Turcicum* leaf blight, *Exserohilum Turcicum*, biological control, *Trichoderma harzianum*, Neem extract, sustainable agriculture, integrated disease management, eco-friendly fungicides

1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops cultivated worldwide and ranks third after wheat and rice in terms of area and production. Owing to its high nutritional value and versatility, maize serves as a staple food for millions of people and is extensively utilized as animal feed and as a raw material in several industrial sectors, including starch, biofuel, pharmaceutical, and food-processing industries. [1-5] In India, maize is cultivated across diverse agro-climatic regions and contributes significantly to agricultural income and food security. However, achieving optimum productivity remains challenging because of several biotic and abiotic constraints, among which foliar diseases constitute a major limiting factor.

Turcicum leaf blight (TLB), also known as northern corn leaf blight, caused by *Exserohilum Turcicum* (Pass.) Leonard and Suggs, is one of the most destructive diseases affecting maize production worldwide. The disease is prevalent in tropical, subtropical, and temperate regions, particularly under conditions of moderate temperature, high relative humidity, prolonged leaf wetness, and frequent rainfall [6-12]. Characteristic symptoms include elongated, elliptical, greyish-green lesions that gradually enlarge and turn tan or necrotic, ultimately leading to extensive leaf blighting. Severe infection causes premature senescence of leaves, reduced photosynthetic efficiency, poor grain filling, and significant yield losses, which may range from 20 to 70% depending on cultivar susceptibility, environmental conditions, and disease severity.

The pathogen survives in infected crop residues and spreads through wind-borne conidia, making disease management difficult under favorable environmental conditions. Conventional control strategies rely heavily on the use of synthetic fungicides and resistant cultivars. Although fungicides provide effective and rapid disease suppression, indiscriminate and prolonged application of chemical pesticides has raised serious concerns regarding environmental pollution, residual toxicity, increased production costs, development of fungicide-resistant pathogen populations, and adverse effects on beneficial microorganisms and ecosystem health. Furthermore, growing awareness regarding food safety and sustainable agricultural practices has necessitated the development of environmentally benign alternatives for disease management.

Eco-friendly disease management approaches involving biological control agents, plant-derived botanicals, and organic amendments have emerged as promising alternatives to conventional fungicides. Beneficial microorganisms such as *Trichoderma harzianum*, *Trichoderma viride*, *Pseudomonas fluorescens*, and *Bacillus subtilis* have demonstrated significant antagonistic activity against several phytopathogenic fungi through mechanisms including mycoparasitism, competition, antibiosis, and induction of systemic resistance. Similarly, botanical extracts obtained from plants such as neem (*Azadirachta indica*), garlic (*Allium sativum*), tulsi (*Ocimum sanctum*), and ginger (*Zingiber officinale*) contain diverse bioactive compounds possessing antifungal, antimicrobial, and antioxidant properties that can effectively suppress pathogen development while minimizing ecological risks [13-15].

Integrated utilization of bioagents and botanicals offers several advantages, including reduced dependence on chemical pesticides, lower environmental contamination, improved soil microbial diversity, enhanced plant growth, and sustainable crop production. Such approaches are consistent with the principles of integrated disease management (IDM) and sustainable agriculture, which emphasize ecological balance and long-term productivity. Moreover, increasing consumer demand for residue-free agricultural products has further accelerated interest in biological and plant-based disease management strategies [16]. Despite considerable progress in the development of eco-friendly technologies, information regarding the comparative efficacy of biological control agents and botanical extracts against *Turcicum* leaf blight under field conditions remains limited. Therefore, there is a need to evaluate sustainable alternatives capable of effectively managing the disease while ensuring environmental safety and economic viability [17-21]. In view of these considerations, the present investigation was undertaken to evaluate the effectiveness of selected eco-friendly and sustainable control measures against *Turcicum* leaf blight of maize and to assess their influence on disease severity, plant growth, and yield attributes under field conditions. The findings of this study may contribute to the development of integrated and environmentally sound disease management strategies for sustainable maize cultivation.

Therefore, the present study was undertaken to evaluate the efficacy of biological and botanical treatments against *Turcicum* leaf blight and their effects on growth and yield of maize under field conditions.

2. Materials and Methods

2.1 Experimental Site and Climatic Conditions

The present investigation was conducted during the Kharif season of 2024-2025 at the Experimental Farm of the KVK Jammu Experimental Farm, located under subtropical climatic conditions. The experimental field was characterized by sandy loam soil with good drainage and a pH ranging from 6.5 to 7.2. The average temperature during the crop-growing period ranged from 22 to 32 °C, with relative humidity varying between 70 and 90%, conditions favorable for the development of *Turcicum* leaf blight. Standard agronomic practices recommended for maize cultivation were followed throughout the experiment.

2.2 Plant Material and Pathogen

A susceptible maize cultivar was used for the study to ensure uniform disease development. *Turcicum* leaf blight was caused by *Exserohilum Turcicum* (Pass.) Leonard and Suggs. Diseased leaf samples exhibiting typical symptoms were collected from naturally infected maize fields. The pathogen was isolated on potato dextrose agar (PDA) medium and purified by single-spore isolation. Identification of the pathogen was performed based on cultural and morphological characteristics.

2.3 Treatments and Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) with three replications. Each treatment plot measured 4 × 3 m with recommended spacing of 60 × 20 cm. Eight treatments comprising biological control agents and botanical extracts were evaluated along with untreated control.

Treatments

- T₁: Seed treatment with *Trichoderma harzianum* (10 g kg⁻¹ seed)
- T₂: Foliar spray of neem seed kernel extract (5%)
- T₃: Foliar spray of garlic extract (10%)
- T₄: Seed treatment with *Pseudomonas fluorescens* (10 g kg⁻¹ seed)
- T₅: *Trichoderma harzianum* + neem seed kernel extract
- T₆: *Pseudomonas fluorescens* + garlic extract
- T₇: Vermicompost application (2 t ha⁻¹) + neem extract
- T₈: Recommended fungicide (Mancozeb 0.25%) (Standard check)
- T₉: Untreated control

2.4 Preparation of Botanical Extracts

Fresh neem seeds and garlic cloves were washed thoroughly and crushed separately using distilled water. The extracts were filtered through muslin cloth and diluted to obtain desired concentrations. Fresh extracts were prepared before each spray to maintain efficacy. Foliar applications were carried out at 45 and 60 days after sowing.

2.5 Disease Assessment

Disease severity was recorded at 75 and 90 days after sowing using a 1-9 scale based on lesion development and percentage leaf area infected. Percent Disease Index (PDI) was calculated using the formula:

$$\text{PDI} = (\text{Sum of numerical ratings} \times 100) / (\text{Total number of leaves observed} \times \text{Maximum disease grade})$$

Disease incidence was determined by counting infected plants and expressing them as percentage of total plants examined.

2.6 Growth and Yield Parameters

Observations were recorded on:

- Plant height (cm)
- Number of leaves plant⁻¹
- Leaf area index
- Cob length (cm)
- Number of grains cob⁻¹
- 1000-grain weight (g)
- Grain yield (t ha⁻¹)

2.7 Statistical Analysis

Experimental data were subjected to analysis of variance (ANOVA) appropriate for Randomized Block Design. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at a significance level of $P \leq 0.05$. Statistical analysis was performed using SPSS version 25.0.

3. Results

3.1 Effect of Eco-Friendly Treatments on Disease Severity

Significant differences among treatments were observed with respect to disease incidence and severity. Among the various treatments, T₅ (*Trichoderma harzianum* + neem seed kernel extract) recorded the lowest disease severity (18.6%) and disease incidence (22.4%), followed by T₆ (*Pseudomonas fluorescens* + garlic extract), which exhibited disease severity of 23.7%. The untreated control recorded the highest disease severity (62.8%) and incidence (71.4%). The combined application of biological control agents and botanical extracts proved more effective than individual treatments, indicating synergistic interactions between antagonistic microorganisms and plant-derived antifungal compounds [22-25].

3.2 Effect on Plant Growth Parameters

Eco-friendly treatments significantly influenced plant growth. Maximum plant height (228.6 cm), number of leaves per plant (14.2), and leaf area index (4.5) were observed in T₅. Enhanced growth might be attributed to improved nutrient uptake and suppression of pathogen activity by beneficial microorganisms [26-30]. Plants treated with *Trichoderma harzianum* showed vigorous growth and greener foliage compared with untreated plants, indicating induction of plant growth-promoting effects.

3.3 Effect on Yield Attributes

Treatments significantly affected yield components. The highest cob length (19.8 cm), grains per cob (514), and 1000-grain weight (312 g) were recorded in T₅, followed by T₆ and T₈. Untreated plants produced shorter cobs with fewer grains and lower grain weight.

Reduction in disease severity contributed to enhanced photosynthetic activity and improved grain filling, thereby

increasing productivity.

3.4 Effect on Grain Yield

Maximum grain yield (7.62 t ha⁻¹) was recorded in T₅, followed by T₆ (7.14 t ha⁻¹) and T₈ (7.30 t ha⁻¹). The untreated control recorded the lowest yield (4.86 t ha⁻¹). Integrated biological and botanical treatments resulted in 56-60% higher yield over control.

These results indicate that eco-friendly management approaches can effectively replace or supplement synthetic fungicides in maize cultivation.

4. Discussion

Turcicum leaf blight is among the most destructive foliar diseases of maize and remains a major challenge in achieving sustainable crop productivity. The present investigation demonstrated that biological control agents and botanical extracts significantly reduced disease severity and improved plant growth and yield. Among the tested treatments, the combined application of *Trichoderma harzianum* and neem seed kernel extract proved superior in suppressing disease development.

The effectiveness of *Trichoderma* species may be attributed to multiple mechanisms, including competition for nutrients, mycoparasitism, production of antifungal metabolites, and induction of systemic resistance in host plants [26-34]. Similarly, neem seed extracts contain azadirachtin, nimbin, and other bioactive compounds that possess potent antifungal properties. The synergistic interaction between microbial antagonists and plant-derived compounds resulted in greater suppression of *Exserohilum Turcicum* compared with individual applications.

Enhanced plant growth and yield observed in treated plants may also be associated with the plant growth-promoting activities of beneficial microorganisms. *Trichoderma* and *Pseudomonas fluorescens* are known to improve nutrient availability, produce phytohormones, and stimulate root development, thereby increasing crop vigor and tolerance against pathogens. Similar findings have been reported by several investigators who demonstrated significant reductions in foliar diseases of maize through integrated biological management approaches.

The results obtained in the present study support the growing emphasis on sustainable agriculture and integrated disease management. Excessive dependence on synthetic fungicides poses risks of environmental contamination, pathogen resistance, and harmful effects on beneficial organisms. In contrast, eco-friendly alternatives provide effective disease suppression while maintaining ecological balance and soil health [35-42]. Therefore, integration of bioagents and botanicals can be considered a promising strategy for sustainable management of *Turcicum* leaf blight in maize. Adoption of these environmentally benign approaches can contribute to reduced chemical inputs, improved crop productivity, and enhanced food security while promoting sustainable agricultural practices [43-46].

Table 1: Treatment details used for the management of *Turicum* leaf blight in maize

Treatment Code	Treatment Description	Method of Application
T ₁	<i>Trichoderma harzianum</i> (10 g kg ⁻¹ seed)	Seed treatment
T ₂	Neem seed kernel extract (5%)	Foliar spray
T ₃	Garlic extract (10%)	Foliar spray
T ₄	<i>Pseudomonas fluorescens</i> (10 g kg ⁻¹ seed)	Seed treatment
T ₅	<i>Trichoderma harzianum</i> + Neem seed kernel extract	Seed treatment + foliar spray
T ₆	<i>Pseudomonas fluorescens</i> + Garlic extract	Seed treatment + foliar spray
T ₇	Vermicompost (2 t ha ⁻¹) + Neem extract	Soil application + foliar spray
T ₈	Mancozeb (0.25%) (Standard check)	Foliar spray
T ₉	Untreated control	—

Table 2: Effect of eco-friendly treatments on disease incidence and severity of *Turicum* leaf blight

Treatment	Disease Incidence (%)	Disease Severity (PDI%)	Disease Reduction over Control (%)
T ₁	34.6	29.8	52.5
T ₂	39.4	35.6	43.3
T ₃	42.7	38.9	38.1
T ₄	37.8	31.4	50.0
T ₅	22.4	18.6	70.4
T ₆	27.9	23.7	62.3
T ₇	32.6	28.5	54.6
T ₈	25.1	20.8	66.9
T ₉ (Control)	71.4	62.8	—

Table 3: Effect of treatments on growth parameters of maize

Treatment	Plant Height (cm)	Number of Leaves Plant ⁻¹	Leaf Area Index
T ₁	212.8	12.8	4.0
T ₂	205.6	12.3	3.8
T ₃	201.7	12.0	3.7
T ₄	209.5	12.6	3.9
T ₅	228.6	14.2	4.5
T ₆	221.4	13.8	4.3
T ₇	214.2	13.0	4.1
T ₈	224.8	14.0	4.4
T ₉ (Control)	186.5	11.1	3.2

Table 4: Effect of eco-friendly treatments on yield attributes of maize

Treatment	Cob Length (cm)	Grains Cob ⁻¹	1000-Grain Weight (g)
T ₁	17.2	438	286
T ₂	16.4	416	278
T ₃	15.8	404	270
T ₄	17.0	430	282
T ₅	19.8	514	312
T ₆	19.1	489	305
T ₇	17.8	452	292
T ₈	19.4	501	308
T ₉ (Control)	14.6	362	248

Table 5: Effect of eco-friendly treatments on grain yield of maize

Treatment	Grain Yield (t ha ⁻¹)	Yield Increase over Control (%)
T ₁	6.72	38.3
T ₂	6.21	27.8
T ₃	5.96	22.6
T ₄	6.58	35.4
T ₅	7.62	56.8
T ₆	7.14	46.9
T ₇	6.85	40.9
T ₈	7.30	50.2
T ₉ (Control)	4.86	—

Table 6: Analysis of variance (ANOVA) for disease severity and grain yield

Parameter	Treatment Mean Square	Error Mean Square	F-value	Significance
Disease severity (%)	482.61	12.84	37.59	P<0.01
Grain yield (t ha ⁻¹)	1.74	0.06	29.00	P<0.01
Plant height (cm)	548.36	18.27	30.01	P<0.01
Cob length (cm)	7.84	0.41	19.12	P<0.01

Values represent means of three replications. Differences among treatments were significant at $p \leq 0.05$ according to Duncan's Multiple Range Test.

5. Conclusion

The present investigation demonstrated that eco-friendly and sustainable management strategies can effectively suppress *Turcicum* leaf blight caused by *Exserohilum Turcicum* in maize while improving crop growth and productivity. Among the various treatments evaluated, the combined application of *Trichoderma harzianum* and neem seed kernel extract proved to be the most effective, resulting in the lowest disease incidence and severity and the highest grain yield. Biological control agents and botanical formulations not only reduced pathogen development but also promoted plant growth and enhanced yield attributes.

The findings of this study emphasize the potential of integrating bioagents and plant-based products as environmentally benign alternatives to synthetic fungicides. Such approaches contribute to reduced chemical inputs, preservation of soil microbial diversity, and maintenance of ecological balance, thereby supporting the principles of sustainable agriculture and integrated disease management. Furthermore, the use of these eco-friendly treatments can minimize the risks associated with fungicide resistance and pesticide residues, while ensuring safer and more sustainable maize production. Overall, the integration of *Trichoderma harzianum* with neem seed kernel extract emerged as a promising strategy for the management of *Turcicum* leaf blight and may be recommended as a component of integrated disease management programs. Further investigations involving multi-location trials, optimization of application schedules, and evaluation under diverse agro-climatic conditions are warranted to validate their long-term efficacy and facilitate large-scale adoption by farmers. The adoption of such sustainable approaches will contribute significantly to enhancing maize productivity, environmental conservation, and global food security.

References

- Agrios GN. Plant pathology. 5th ed. Elsevier Academic Press; 2005.
- Andrivon D, Lucas JM, Guérin C. Development of resistance to metalaxyl in populations of *Phytophthora infestans* in France. Plant Pathol. 1997;46(5):688-697.
- Aneja KR. Experiments in microbiology, plant pathology and biotechnology. 4th ed. New Age International Publishers; 2003.
- Anonymous. Agricultural statistics at a glance. Ministry of Agriculture and Farmers Welfare, Government of India; 2023.
- Arun Kumar K, Lal HC, Akhtar J. Management of *Turcicum* leaf blight of maize by fungicides. Indian Phytopathol. 2008;61(3):332-335.
- Bunker RN, Mathur K, Bohra B. Efficacy of plant extracts and bioagents against *Exserohilum Turcicum* causing leaf blight of maize. J Mycol Plant Pathol. 2011;41(3):456-460.
- CIMMYT. Maize diseases: A guide for field identification. International Maize and Wheat Improvement Center; 2022.
- Cook RJ, Baker KF. The nature and practice of biological control of plant pathogens. American Phytopathological Society; 1983.
- Dhingra OD, Sinclair JB. Basic plant pathology methods. 2nd ed. CRC Press; 1995.
- Dubey SC, Suresh M, Singh B. Evaluation of *Trichoderma* species against *Fusarium* wilt pathogens. Biol Control. 2007;40(2):157-162.
- FAO. FAOSTAT statistical database. Food and Agriculture Organization of the United Nations; 2022.
- Gupta RP, Singh A. Integrated management of foliar diseases in maize. J Cereal Res. 2018;10(2):145-153.
- Harlapur SI, Wali MC, Kulkarni MS, Benagi VI, Patil BC. Status of *Turcicum* leaf blight of maize and its management. Karnataka J Agric Sci. 2008;21(4):573-576.
- Harman GE. Overview of mechanisms and uses of *Trichoderma* spp. Phytopathology. 2006;96(2):190-194.
- Harman GE, Howell CR, Viterbo A, Chet I, Lorito M. *Trichoderma* species: Opportunistic avirulent plant symbionts. Nat Rev Microbiol. 2004;2(1):43-56.
- Kumar A, Sharma RC, Singh PK. Integrated disease management strategies for maize foliar diseases. Indian J Agric Sci. 2014;84(10):1175-1180.
- Lal HC, Kumar B. Biological management of *Turcicum* leaf blight of maize caused by *Exserohilum Turcicum*. J Mycol Plant Pathol. 2011;41(2):243-247.
- Thomas S, Mathew L. Plant growth promoting rhizobacteria enhancing vigour and yield: A brief review. Agric Arch. 2024;10.
- Mahesh M, Saifulla M, Harlapur SI. Evaluation of bioagents and botanicals against *Exserohilum Turcicum* under field conditions. Plant Dis Res. 2013;28(1):55-59.
- Munkvold GP, White DG. Compendium of corn diseases. 4th ed. American Phytopathological Society; 2016.
- Tripathi S, Srivastava D. *Trichoderma* as a green catalyst: Exploring its versatile roles in sustainable agriculture. Microbiol Arch Int J. 2025.
- Nene YL, Thapliyal PN. Fungicides in plant disease control. 3rd ed. Oxford and IBH Publishing Co.; 1993.
- Olubunmi-Ajayi TS, Akinrinola OO, Ibrahim A, Adeyemi IO. Assessing technical, economic, and allocative efficiencies of maize-rice-based farmers across scale economies in Southwest Nigeria. Agric Arch Int J. 2025.
- Sakhong R, Kehokhunu NFK, Pande KK, Solanki P, Kumari S. Agronomic bio-fortification of cereals with zinc to overcome the malnutrition from Indian population. Agric Arch Int J. 2024;30.

25. Pandey KK, Pandey PK, Kalloo G, Banerjee MK. Resistance to early blight in tomato and mechanisms of resistance. *J Plant Pathol.* 2003;85(2):93-102.
26. Pithiya MB, Sharma SK, Sharma M, Sharma MN. Advancements and challenges in plant tissue culture: A comprehensive overview. *J Plant Biota.* 2022.
27. Patel PR, Patel DS. Eco-friendly management of maize diseases using botanicals and bioagents. *Int J Curr Microbiol Appl Sci.* 2017;6(7):1436-1443.
28. Vishwakarma BH, Yadav NR, Yadav AR, Pandey S, Sharma VV, Yadav AU, *et al.* Integrative plant systems biology: Linking physiology, metabolism, ecology, and biotechnology for climate-resilient crop improvement. *Plant Sci Rev.* 2026.
29. Paul PA, Lipps PE, Madden LV. Meta-analysis of yield response to fungicide application in maize. *Phytopathology.* 2011;101(10):1122-1132.
30. Prasad RD, Rangeshwaran R, Anuroop CP, Rashmi HJ. Biological control of plant diseases through fungal antagonists. *Curr Sci.* 2002;83(12):1460-1468.
31. Arya M. Polyploidy and hybrid vigour: Untapped resources for next-generation crop productivity. *Plant Sci Rev.* 2022.
32. Kangor WR, Ayabei K. Study of novel *Saccharomyces cerevisiae* isolated from finger millet for sustainable bioethanol production in Kenya. *Agric Arch Int J.* 2026.
33. Rani I, Sharma A, Devi P. Antifungal activity of neem and garlic extracts against fungal pathogens of maize. *Int J Chem Stud.* 2020;8(3):1825-1830.
34. Kadam RG, Ghutke TD. Impact of organic additives on non-enzymatic antioxidant activity in *Lentinus edodes* (Berkley). *Environ Rep Int J.* 2022.
35. Rajan VV, Kumari A. Advances in cereal genomics and applications in plant breeding. *Plant Sci Rev.* 2025.
36. Ayana DT, Olika GI. Effect of mulching practice as soil moisture conservation for tomato (*Lycopersicon esculentum* Mill.) production under supplemental irrigation in Yabello district of Borana zone, Ethiopia. *Acta Biol Forum.* 2024;3(2):43-47.
37. Reddy PP. Recent advances in crop protection. Springer; 2013.
38. Shaner G, Finney RE. The effect of nitrogen fertilization on expression of slow-mildewing resistance in wheat. *Phytopathology.* 1977;67(8):1051-1056.
39. Singh D, Singh HB. Biological control of plant pathogens using *Trichoderma* species. *Indian J Mycol Plant Pathol.* 2004;34(2):153-157.
40. Singh RS. Introduction to principles of plant pathology. 4th ed. Oxford and IBH Publishing Co.; 2006.
41. Abdulrasool MM, Zainab RM. Comparative analysis of heavy metal accumulation in soils near industrial complexes and their uptake in edible plants. *Plant Sci Rev.* 2024.
42. White DG. Compendium of corn diseases. 3rd ed. American Phytopathological Society Press; 1999.
43. Yadav OP, Hossain F, Karjagi CG, Kumar B, Zaidi PH, Jat SL, *et al.* Genetic improvement of maize in India and its impact. *Agric Res.* 2015;4(4):325-338.
44. Zadoks JC, Schein RD. Epidemiology and plant disease management. Oxford University Press; 1979.
45. Goud VV, Kumar AS, Swapna N. The role of plant genetic resources in biodiversity conservation and sustainable agriculture. *Plant Sci Rev.* 2023.