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Ecology, Seasonal Dynamics, and Bioindicator Potential of *Trombidium grandissimum* (Red Velvet Mite) in Dryland Agroecosystems of Telangana, India

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Abstract

Red velvet mites (*Trombidium grandissimum*) are ecologically important soil arthropods that function as predators and bioindicators of soil health. The present study investigates the seasonal dynamics and ecological distribution of T. grandissimum in selected dryland agroecosystems of Telangana, India, during the 2023 monsoon season. Field surveys were conducted in Palem, Thuljaraopet, and Pedda Padishala using pitfall traps, hand collection, and Tullgren funnel extraction methods. Mite activity was restricted to the early monsoon period (May–August), with peak abundance recorded in July (72 individuals/m² at Palem). Significant variation in population density was observed among sites, with higher abundance in red sandy loam soils under organic farming, whereas lower abundance was recorded in black cotton soils subjected to intensive pesticide use. Soil organic carbon showed a strong positive correlation with mite abundance ($r = 0.86$, $p < 0.01$), demonstrating its key role in supporting soil fauna. The results confirm the influence of soil properties and agricultural practices on mite distribution and establish T. grandissimum as a reliable bioindicator of soil health. The study highlights the importance of sustainable farming practices for conserving soil biodiversity and enhancing ecosystem functioning in dryland agroecosystems.

Keywords: *Trombidium grandissimum* (red velvet mite), soil biodiversity, agroecology, bioindicator, monsoon dynamics, Telangana

1. INTRODUCTION

Soil ecosystems represent one of the most biologically complex and dynamic components of terrestrial environments, supporting a vast diversity of organisms that regulate essential ecological processes such as nutrient cycling, decomposition, and biological pest control. Among soil microarthropods, mites constitute one of the most abundant and functionally diverse groups, occupying multiple trophic levels within the soil food web (Proctor & Owens, 2000; Walter & Proctor, 2013). Due to their high sensitivity to environmental disturbances, soil mites are widely recognized as reliable indicators of soil health and ecosystem stability

(Verma, 2014; Bhowmik & Das, 2017). Recent global studies have further emphasized their role in monitoring soil biodiversity under changing climatic and land-use conditions (Bardgett & van der Putten, 2023; Gardi et al., 2022).

Red velvet mites (*Trombidium grandissimum*), belonging to the family Trombidiidae (Parasitengona), are among the most conspicuous members of soil mesofauna in tropical and semi-arid ecosystems. These mites exhibit a complex life cycle characterized by ectoparasitic larval stages and free-living predatory nymphs and adults (Robaux, 1974; Southcott, 1986; Zhang et al., 1995). This dual ecological role enhances their significance in regulating soil arthropod populations and maintaining ecological balance in agroecosystems.

In India, red velvet mites are typically observed during the onset of monsoon rains, particularly in June and July, when soil moisture conditions become favorable (Henking, 1882; Hill, 1905; Reddy & Basha, 2019). Their emergence is closely synchronized with rainfall patterns, which trigger the activation of dormant stages and enhance soil biological activity. As generalist predators, adult mites feed on insect eggs, larvae, and other small arthropods, thereby contributing to natural pest regulation (Dong et al., 1996; Ranganath, 2001). This ecological role has gained importance in the context of sustainable agriculture and integrated pest management (IPM), where biological control agents are increasingly preferred over chemical pesticides (Gerson & Weintraub, 2021).

The abundance and distribution of *T. grandissimum* are strongly influenced by soil physicochemical properties, particularly organic carbon content, nutrient status, and moisture availability. Soils rich in organic matter provide favorable conditions for microbial growth and support diverse soil fauna, thereby enhancing trophic interactions (Proctor & Owens, 2000; Bhowmik & Das, 2017). In contrast, intensive agricultural practices involving excessive pesticide use and soil disturbance can significantly reduce soil biodiversity, including beneficial mite populations (Ranganath, 2001; Chauhan et al., 2015). Recent ecological studies have highlighted that conservation-oriented farming practices, such as reduced chemical input and organic amendments, are essential for maintaining soil biodiversity and ecosystem resilience (Bardgett & van der Putten, 2023; Gardi et al., 2022).

Climatic factors, particularly rainfall and soil moisture, play a critical role in regulating the seasonal dynamics of soil mites. Moisture availability influences their emergence, activity, and reproductive cycles, with peak abundance often observed during favorable environmental conditions (Wall et al., 2021). In the case of *T. grandissimum*, emergence is closely associated with early monsoon rainfall, indicating strong ecological adaptation to semi-arid environments (Paramesh & Vijayagiri, 2021).

However, no systematic ecological study has been conducted on the seasonal dynamics and soil- environment interactions of *T. grandissimum* in the semi-arid agroecosystems of Telangana. Most available research has been conducted in central, northern, and northeastern regions (Singh et al., 2021; Deka & Mahanta, 2021), while the dryland agroecosystems of Telangana remain largely unexplored. These ecosystems are characterized by erratic rainfall, diverse soil types, and varying agricultural practices, providing an ideal setting to investigate the interactions between soil fauna, environmental factors, and anthropogenic influences.

Therefore, the present study aims to investigate the ecology and seasonal dynamics of *T. grandissimum* in selected dryland agroecosystems of Telangana during the 2023 monsoon season, with a focus on understanding the influence of soil properties and farming practices on mite abundance and evaluating their potential as bioindicators of soil health.

2. MATERIALS AND METHODS

Study Area: The present study was conducted in three representative dryland agroecosystems of Telangana, India, selected based on prior cropping history (2022), soil characteristics, and variation in agricultural practices. The selected sites included Palem village in Nalgonda district (16.9785° N, 79.2551° E), Thuljaraopet village in Suryapet district (17.1197° N, 79.6563° E), and Pedda Padishala village in Yadadri-Bhuvanagiri district (17.3386° N, 79.0211° E). The study sites differed in cropping systems during the previous agricultural year: Palem was predominantly cultivated with red gram (*Cajanus cajan*), Thuljaraopet with cotton (*Gossypium spp.*), and Pedda Padishala with green gram (*Vigna radiata*). These regions fall under semi-arid climatic conditions characterized by hot summers and seasonal monsoon rainfall. The soils varied from red sandy loam (Palem) to black cotton soil (Thuljaraopet) and sandy loam (Pedda Padishala), providing contrasting edaphic environments for evaluating soil fauna dynamics (Fig.1).

Fig. 1. Study sites showing dryland agroecosystems of Palem, Thuljaraopet and Peddapadishala villages

Study Duration: Field investigations were conducted from May to December 2023. Sampling of red velvet mites (*T. grandissimum*) was carried out during the early monsoon period, from May (following the first rainfall) to August.

Experimental Design: At each study site, three plots of 12 × 12 m were selected to ensure replication and minimize spatial variability. Thus, a total of nine plots were established across the three locations. Sampling was conducted at 15-day intervals during the active period (May- August 2023). Plot selection was based on uniformity in soil type, crop condition, and management practices within each site.

Sampling Techniques: To capture both surface-active and soil-dwelling stages of mites, a combination of standard sampling techniques was employed:

Pitfall Trap Method: Pitfall traps were used to collect surface-active mites. Five traps were installed randomly in each plot, resulting in a total of 45 pitfall traps (5 traps × 3 plots × 3 sites) during each sampling period. Each trap consisted of a plastic container (approximately 10 cm in diameter and 15 cm in depth) buried flush with the soil surface. The traps were partially filled with 70% ethanol containing a few drops of glycerol to preserve specimens and reduce evaporation. Traps were left in the field for 48 hours during each sampling period, after which the collected specimens were transferred to labeled vials for identification (Southwood & Henderson, 2000).

Hand Collection: Direct hand collection was carried out during early morning hours (06:00- 08:00 AM), when red velvet mites are most active on the soil surface. Individuals were carefully collected using soft brushes or forceps to avoid damage and preserved in 70% ethanol for further examination.

Tullgren Funnel Extraction: Soil samples (approximately 500 g per plot) were collected from a depth of 5-10 cm and processed using Tullgren funnels to extract soil-dwelling and immature stages of mites. Samples were exposed to a gradual heat source for 48 hours, forcing organisms to move downward into collecting containers filled with ethanol (Macfadyen, 1961).

Soil Sampling and Physicochemical Analysis: Soil samples were collected monthly from each plot and analyzed for key physicochemical parameters: Soil Organic Carbon (%) Determined using the Walkley- Black dichromate oxidation method (Walkley & Black, 1934). Nitrogen (N) was estimated using the Kjeldahl method (Kjeldahl, J. 1883), while phosphorus (P) and potassium (K) were determined using standard spectrophotometric techniques. Soil Ph Measured using a digital pH meter in a soil–water suspension (1:2.5 ratio). Soil Moisture Content (%): Determined by gravimetric method. All analyses were conducted following standard soil science protocols (Jackson, 1973).

Assessment of Farming Practices: Information regarding cropping patterns, pesticide application, and field management practices was collected through direct field observations and farmer interviews. Based on pesticide usage intensity and cropping systems, the sites were categorized as: organic system (red gram cultivation, Palem), low-input system (green gram cultivation, Pedda Padishala), and high-input conventional system (cotton cultivation, Thuljaraopet). This classification was used to evaluate the influence of anthropogenic factors on mite abundance.

Species Identification: Collected specimens were examined under a stereozoom microscope and identified using standard acarological keys and taxonomic literature (Robaux, 1974; Southcott, 1986; Zhang et al., 1995). Identification was based on morphological characteristics such as body size, coloration, setae distribution, and appendage structure.

Statistical Analysis: Mite abundance was expressed as the number of individuals per square meter (individuals/m²). Statistical analyses were performed using *SPSS version 25.0*. The following analyses were conducted: Descriptive statistics to summarize abundance data. One-way Analysis of Variance (ANOVA) to compare mite populations across sites. Pearson correlation analysis to determine relationships between mite abundance and soil parameters. Regression analysis was performed to evaluate the influence of environmental variables on mite distribution. All statistical tests were conducted at a significance level of $p < 0.05$ (Gomez & Gomez, 1984).

3. RESULTS

This study investigated the ecology and seasonal dynamics of *T. grandissimum* in selected dryland agroecosystems of Telangana during the 2023 monsoon season, with a focus on understanding the influence of soil properties and farming practices on mite abundance and evaluating their potential as bioindicators of soil health. Field surveys were conducted in Palem, Thuljaraopet, and Pedda Padishala using pitfall traps, hand collection, and Tullgren funnel extraction methods.

Seasonal Occurrence and Population Dynamics: The occurrence of *T. grandissimum* in the study area was strictly seasonal and confined to the early monsoon period (May- August 2023). No individuals were recorded from September to December, indicating that the species exhibits a well-defined life cycle synchronized with monsoon rainfall.

A progressive increase in mite density was observed from May to July across all three study sites, followed by a sharp decline in August (Fig. 2). The initial emergence in May corresponded with the first rainfall, while peak abundance in July coincided with maximum soil moisture conditions.

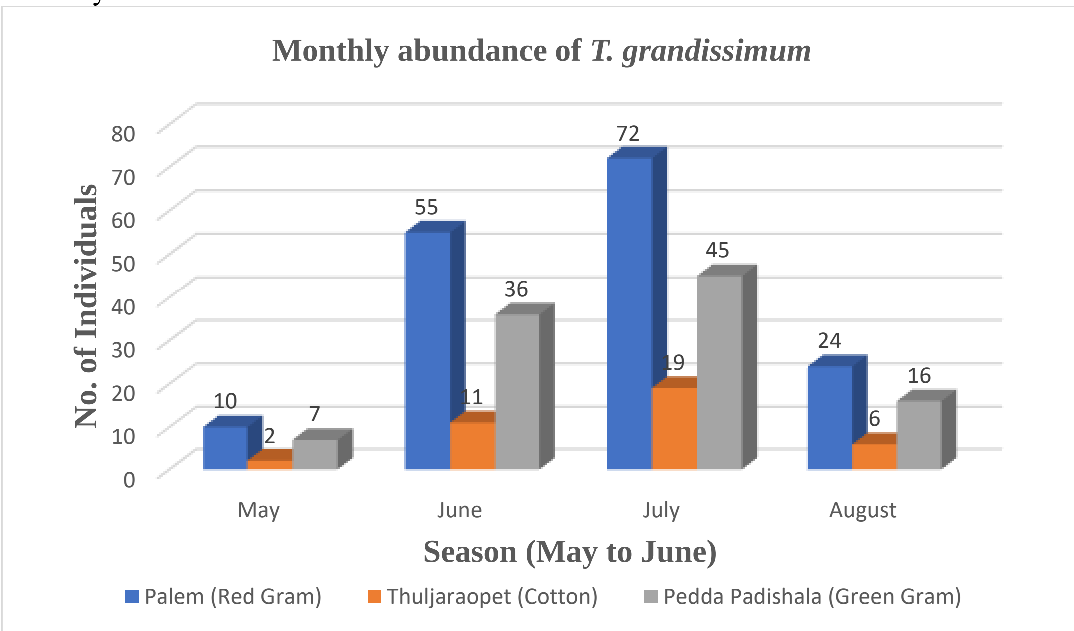

Fig. 2. Monthly abundance of *T. grandissimum* (individuals/m²)

Mite density increased from May to July at all sites, with peak abundance recorded in July. Palem recorded the highest population (72 individuals/m²) during this period. Thuljaraopet consistently showed the lowest abundance. A decline of approximately 60–70% in August was observed.

Spatial Variation in Mite Abundance: Considerable variation in mite abundance was observed among the three study sites. Palem consistently recorded the highest density, followed by Pedda Padishala, while Thuljaraopet recorded the lowest population throughout the study period (Table 1).

Table 1. Site-wise variation in mite abundance and soil characteristics

Location	Soil Type	Organic Carbon (%)	Avg. Mites/m²	Pesticide Use
Palem	Red sandy loam	1.82	55	Nil
Thuljaraopet	Black cotton	0.42	10	High
Pedda Padishala	Sandy loam	1.18	35	Low

Palem exhibited the highest mean density (55 individuals/m²), which was significantly higher than that of the other sites (ANOVA, $p < 0.05$). Thuljaraopet recorded the lowest density (10 individuals/m²). Pedda Padishala showed intermediate abundance.

Influence of Soil Physicochemical Properties: Soil physicochemical parameters, particularly organic carbon and nutrient content, showed a strong influence on mite abundance. A positive correlation was observed between organic carbon and mite density (Table 2).

Table 2. Comparison of soil nutrients in mite-rich and mite-poor soils

Parameter	Mite-rich Soils	Mite-poor Soils
Organic Carbon (%)	1.68	0.36
Nitrogen (kg/ha)	310	85
Phosphorus (kg/ha)	240	62
Potassium (kg/ha)	332	57

Mite-rich soils contained significantly higher nutrient levels, with organic carbon nearly five times greater than mite-poor soils. Correlation analysis revealed a strong positive relationship between organic carbon and mite abundance ($r = 0.86$, $p < 0.01$).

Effect of Farming Practices: Farming practices, particularly pesticide use, had a significant influence on mite abundance across the study sites (Table 3).

Table 3. Effect of farming practices on mite abundance

Farming Type	Location	Pesticide Level	Mite Density (individuals/m²)
Organic Farming	Palem	Nil	High (55)
Semi-organic	Pedda Padishala	Low	Moderate (35)
Conventional	Thuljaraopet	High	Low (10)

Organic farming systems supported significantly higher mite populations compared to conventional systems ($p < 0.05$). High pesticide input in Thuljaraopet resulted in the lowest abundance.

Relationship with Rainfall and Soil Moisture: Mite emergence and population dynamics were closely associated with rainfall patterns and soil moisture conditions (Table 4).

Table 4. Relationship between rainfall phase and mite activity

Period	Rainfall Condition	Mite Activity Level
May	Initial rainfall	Low (Emergence)
June	Moderate rainfall	Increasing
July	Peak rainfall	Maximum
August	Declining rainfall	Decreasing

The initial emergence of mites in May corresponds to the onset of rainfall. Peak activity was recorded in July, while reduced rainfall in August led to a decline in population density.

Overall Ecological Trends: The combined analysis of seasonal, spatial, and environmental factors revealed clear ecological preferences of *T. grandissimum* (Table 5).

Table 5. Summary of ecological preferences of *T. grandissimum*

Factor	Favorable Condition	Unfavorable Condition
Soil Organic Carbon	High	Low
Soil Type	Sandy loam / Red soils	Black cotton soil
Soil Moisture	Moderate to high	Low

Pesticide Use	Nil / Low	High
Farming System	Organic	Conventional

The species thrives in nutrient-rich, moist, and minimally disturbed soils. Poor soil conditions and high pesticide use significantly reduce its abundance.
The observed relationship between mite abundance and soil organic carbon, nutrient levels, and pesticide use indicates the suitability of *T. grandissimum* as a potential bioindicator of soil health.

4. DISCUSSION

The present study provides a comprehensive understanding of the ecology and seasonal dynamics of *T. grandissimum* in dryland agroecosystems of Telangana. The findings clearly indicate that the occurrence, abundance, and distribution of this species are strongly regulated by seasonal rainfall, soil physicochemical properties, and agricultural management practices.
The strictly seasonal occurrence of *T. grandissimum*, confined to the early monsoon period (May- August), highlights the critical role of rainfall as a primary ecological driver. The progressive increase in mite density from May to July, followed by a sharp decline in August, reflects a life cycle that is highly synchronized with monsoon rainfall patterns. Soil moisture enhances microbial decomposition processes and increases the availability of prey organisms, thereby supporting population buildup of predatory mites. Similar ecological relationships between soil moisture and faunal activity have been widely documented (Wall et al., 2021; Bardgett & van der Putten, 2023).
One of the most significant findings of the present study is the strong positive correlation between soil organic carbon and mite abundance ($r = 0.86$, $p < 0.01$). Organic carbon is a key determinant of soil biological activity, as it supports microbial biomass and nutrient cycling. Increased microbial activity promotes the proliferation of soil microarthropods, which serve as prey for predatory mites such as *T. grandissimum*. Similar relationships have been reported in earlier studies (Proctor & Owens, 2000; Bhowmik & Das, 2017; Kothari et al., 2020). Recent global assessments have further emphasized that soil organic carbon is a major driver of belowground biodiversity and ecosystem functioning (Bardgett & van der Putten, 2023; Gardi et al., 2022).
The observed spatial variation in mite abundance among the study sites reflects the influence of soil type. Agricultural practices further contributed to these differences. The higher abundance recorded in Palem can be attributed to favorable soil conditions, including better aeration, moderate moisture retention, and higher organic carbon content. In contrast, the lower abundance observed in Thuljaraopet may be due to the compact nature of black cotton soils and intensive pesticide usage. The adverse effects of pesticides on soil biodiversity have been extensively reported, with studies demonstrating that chemical inputs reduce both target and non-target organisms and disrupt soil food webs (Ranganath, 2001; Chauhan et al., 2015; Sánchez-Bayo & Wyckhuys, 2019).
The intermediate mite abundance observed in Pedda Padishala suggests that moderate soil fertility and reduced pesticide input can support sustainable populations of soil fauna. This observation is consistent with findings from agroecological studies indicating that low-input and semi-organic systems maintain higher biodiversity compared to intensive conventional systems (Kothari et al., 2020; Deka & Mahanta, 2021).
The strong association between rainfall patterns and mite activity observed in this study further emphasizes the importance of climatic factors in regulating soil fauna. Soil moisture not only facilitates mite emergence and movement but also enhances microbial activity and nutrient cycling. Such relationships have been highlighted in broader ecological studies, where moisture is considered a key driver of soil biodiversity and ecosystem processes (Wall et al., 2021).
The present study also confirms the potential of *T. grandissimum* as a bioindicator species. The clear relationship between mite abundance and soil quality parameters, particularly organic carbon, nutrient status, and pesticide use, demonstrates their sensitivity to environmental disturbances. Bioindicator species are widely used in ecological monitoring as they provide integrated information about ecosystem health (Verma, 2014; Gardi et al., 2022).
From an applied perspective, red velvet mites play an important role in agroecosystems as natural predators. By feeding on insect eggs and larvae, they contribute to biological pest control and reduce reliance on chemical pesticides. This ecological function is particularly important in the context of integrated pest management (IPM), where biological control agents are increasingly promoted (Gerson & Weintraub, 2021; van Lenteren et al., 2020).
The higher nutrient levels observed in mite-rich soils further indicate a strong link between soil fertility and biological activity. Enhanced levels of nitrogen, phosphorus, and potassium support plant growth and microbial

processes, which indirectly influence soil fauna abundance. This interconnected relationship between soil fertility, microbial activity, and biodiversity highlights the importance of sustainable soil management practices (Bardgett & van der Putten, 2023).

In the context of increasing agricultural intensification and environmental change, the conservation of soil biodiversity has become critically important. The findings of this study emphasize that sustainable farming practices, including reduced pesticide use and enhancement of soil organic matter, are essential for maintaining soil biodiversity and ecosystem functioning. Such practices not only support beneficial organisms like red velvet mites but also contribute to long-term agricultural sustainability.

Overall, the study demonstrates that *T. grandissimum* is a sensitive and reliable bioindicator species, and its presence can be effectively used to assess the ecological status of dryland agroecosystems. Future research should focus on long-term monitoring, molecular characterization, and integration of soil biodiversity into agricultural management strategies.

5. CONCLUSION

The present study establishes *T. grandissimum* as a sensitive bioindicator of soil health in dryland agroecosystems. Its seasonal occurrence is closely linked to monsoon rainfall, while its abundance is strongly influenced by soil organic carbon, moisture availability, and agricultural practices. The significantly higher populations observed in organically managed soils emphasize the importance of reduced chemical inputs for sustaining soil biodiversity. The strong relationship between mite abundance and soil quality parameters highlights the ecological significance of this species in assessing soil health. These findings underscore the need for conservation-oriented farming practices to maintain soil biodiversity, enhance ecosystem functioning, and ensure long-term agricultural sustainability in dryland regions.

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