Dry Root Rot of Chickpea: An Emerging Threat Under Changing Climate and Its Ecofriendly Management Through Endophytic Bacteria

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Introduction

Chickpea (*Cicer aritenium L.*) is an important food crop mainly by small and subsistence farmers in the semi-arid tropics of Asia and Africa. It is cultivated in more than 50 countries across Asia, Africa and America. The global annual production is about 10.9 million tons from almost 12 million hectares. South Asia produces most of the world's chickpea and India is the largest producer with around 7 million tons yearly. Chickpea is the fifth most important legume in the world, with India contributing the largest share of its production. Chickpea is grown in different seasons depending on the region. It is a spring crop in countries like the USA, Turkey and Mediterranean areas, but a winter crop in Southeast Asia. In India, it is grown during the rabi season (October-March). Chickpea is a major protein rich crop cultivated in many countries mainly in rainfed areas.

Climate change is now a major problem for chickpea farming, affecting both yield and overall production. Weather extremes such as drought, very high temperatures, cold spells, and too much rainfall are reducing chickpea yields in many parts of the world. Among these climate factors, drought and heat are the most damaging and are responsible for nearly half of the total yield loss. Chickpea is usually planted after cereal crops and depends on the leftover soil moisture, so it often faces water shortage toward the end of the season along with periods of heat stress. These conditions usually occur during the plant's reproductive stage, leading to significant yield reduction. Additionally, dry root rot, an important disease in chickpea, becomes more severe when temperatures are high and the soil is dry, making the crop even more vulnerable under stress (Mirchandani *et al.*, 2023).

Rhizoctonia bataticola:

It is an anamorphic fungal genus belonging to the class Agaricomycetes, order Cantharellales and family Ceratobasidiaceae. These fungi lack spore production and instead consist mainly of hyphae and sclerotia. Under laboratory conditions the fungus shows fast growth on potato dextrose agar developing brown to grey mycelium that darkens as it matures. Initially, the hyphae are thin, transparent, non-septate and exhibit dichotomous branching, eventually giving rise to typical black sclerotia. The organism may produce profuse aerial mycelium that reaches the lid of the culture plate although in some cases mycelial growth may be partially or fully suppressed. *Rhizoctonia bataticola* is distinguished by its right angled branching pattern with a slight constriction at the point where the branch arises. Its sclerotia are black, smooth and vary in shape from spherical to oblong or irregular.

Dry root rot symptoms

Dry root rot in chickpea typically appears around the flowering to post-flowering stage, beginning with yellowing of leaves that starts at the lower canopy and gradually progresses upward. Affected plants remain upright but their leaves and stems become dry, brittle, and straw-coloured, leading to premature drying nearly ten days to several weeks before normal crop maturity. These plants often exhibit poor pod development, with small, shriveled pods compared to healthy plants that dry uniformly only after reaching full maturity. The disease originates in the roots, where the taproot and lateral roots develop brown to black lesions that progress into severe rotting. As the infection advances, most lateral and fine roots detach, the taproot becomes dark, brittle, and shredded, and the bark peels away easily. Small black microsclerotia form inside the root tissues, blocking water and nutrient movement, which results in the sudden drying of the aerial parts. Infected plants can be pulled from the soil with little resistance because much of the root system has decayed, while pieces of the rotted root often break off and remain in the soil, serving as a source of inoculum for subsequent crops (Sharma *et al.*, 2015).

Epidemiology

Epidemiology deals with how infectious diseases begin and spread. According to the disease tetrahedron concept, for any disease to develop four essential components must interact: a virulent pathogen, a susceptible host, conducive environmental conditions and adequate time. Microsclerotia are the primary inoculum of the pathogen and can remain viable in soil for nearly 15 years. They usually occur in clusters on the soil surface and up to a depth of 0-20 cm. These structures are known for their strong ability to survive harsh and unfavourable environmental conditions. The optimum temperature for microsclerotia germination is around 28-35 °C. After germination, the germ tube forms an appressorium, which helps the fungus penetrate the host tissue by releasing cell wall degrading enzymes. The pathogen then grows through the cortex, reaches the xylem vessels and colonizes the vascular system. The amount of sclerotia produced by *R. bataticola* depends on the host plant and the specific characteristics of the fungal isolate. *R. bataticola* can survive in soil or crop debris for 2-15 years and is highly influenced by environmental factors rather than the presence of host tissue. Factors such as repeated freezing and thawing of soil, low carbon-to-nitrogen ratio and soil moisture level significantly affect microsclerotia longevity. Dry soil promotes microsclerotia formation whereas high soil moisture suppresses their production.

Disease rating scale on 1 - 9 scale for dry root rot of chickpea

Rating	Observation
1	No infection on roots
>1 and <3	Very few small lesions (black discoloration) on roots
>3 and <5	Lesions (black discoloration) on roots clear but less; new roots free from infection
>5 and <7	Lesions (black discoloration) on roots more; many new roots generally free from lesions
>7	Roots infected and completely discoloured (black)

Climate change intensifies DRR

Drought and heat stress are major climatic factors that intensify dry root rot (DRR) in chickpea and severely reduce yield. In drought-prone regions, susceptible cultivars may suffer yield losses ranging from 40% to complete crop failure, especially when drought coincides with high temperatures (Rai *et al.*, 2022). Much of India's chickpea-growing area frequently experiences moisture stress, which begins as the crop shifts from vegetative to reproductive stages and becomes more severe with late sowing. Low soil moisture and high temperatures together favour the germination, infection, and spread of *R. bataticola*, leading to greater disease incidence during flowering and podding stages when DRR symptoms peak. Heat stress further worsens the situation, as temperatures around 35°C promote rapid pathogen growth, increased production of cellulolytic enzymes, and faster colonization of root tissues (Sharma *et al*, 2013). Since the pathogen tolerates heat better than the host plant, warm and dry conditions significantly accelerate DRR development, resulting in premature plant drying and substantial yield loss.

Role of endophytic bacteria in suppressing dry root rot of chickpea

Endophytic bacteria inhabit plant tissues without causing harm and play a key role in enhancing plant growth and health. They improve nutrient uptake, produce growth promoting hormones like auxins, cytokinins and gibberllins and enhance root architecture for better water and nutrient absorption. Many endophytes can solubilize essential nutrients such as phosphorus and potassium and fix atmospheric nitrogen.

In chickpea endophytes support plant growth, boost nutrient acquisition and increase tolerance to abiotic stresses like drought and biotic stresses like pathogens. They also reduce oxidative damage by producing protective enzymes and metabolites. Several endophytes synthesize antimicrobial compounds, lytic enzymes and volatile substances that suppress fungal pathogens and activate systematic plant defenses including the production of phytoalexins and pathogenesis related proteins. The endophytes act as biocontrol agents by inhibiting pathogens through the production of antifungal or antibacterial substances like siderophores, antibiotics and hydrogen cyanide.

Endophytic bacteria play a crucial role in helping chickpea plants defend themselves against *Rhizoctonia bataticola*, the causal agent of dry root rot. These beneficial microbes live inside plant tissues and can directly inhibit the fungus by producing antifungal compounds, lytic enzymes such as chitinase and glucanase, and volatile substances that slow down fungal growth. Many chickpea-associated endophytes, including *Bacillus*, *Pseudomonas*, and certain actinobacteria, are known to release metabolites that suppress mycelial development and limit sclerotia formation (Abdullaeva *et al.*, 2024). By colonizing roots and competing for nutrients and space, endophytes also reduce the chances of the pathogen successfully infecting the plant.

In addition to direct antagonism, endophytic bacteria strengthen the plant's internal defense system. They activate induced systemic resistance (ISR), which prepares the plant to respond more quickly and effectively when the pathogen attempts to invade. These microbes also support the plant under drought the environmental condition that most strongly favors dry root rot. Traits such as ACC-deaminase activity, production of growth hormones, and enhancement of nutrient uptake help plants maintain healthier root systems even when water is limited. This improved stress tolerance reduces the susceptibility of chickpea roots to attack by *R. bataticola*.

Together, these mechanisms make bacterial endophytes valuable allies for managing dry root rot in chickpea. Their ability to combine antifungal activity with drought-relief benefits is especially important because the disease is most severe under moisture stress. Identifying and applying efficient endophytic strains either individually or as microbial consortia offers a promising, eco-friendly strategy to enhance chickpea health and reduce disease losses.

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