International Journal For Research In Agricultural And Food Science

GREEN PUBLICATION

ISSN (Online): 2208-2190
Volume 12 Issue 01 April 2026
Available on-line at: https://ijfres.com/index.php/es/about

DOI:*https://doi.org/10.53555/es.v11i1.xyz* *Received: 15-Mar-2026 Accepted: 10-April-20*

ROLE OF PARVULIN-TYPE PPIASES IN SOIL FERTILITY

Khanchuila Shingnaisui[1*] Sukh Sandan[1], Avanish Kumar Shrivastav[2]

[1]Department of Zoology, Sri Venkateswara College, University of Delhi, Delhi-110021, India.
[2]Department of Zoology, Maitreyi College, University of Delhi, Delhi-110021, India.

***Corresponding author:** Khanchuila Shingnaisui*
**Email: khanchuilashingnaisui@south.du.ac.in*

Abstract
Ecosystem sustainability and soil fertility are the important components for the modern agricultural applications. These depend largely on the functional stability of soil microbiota, which drive specific processes such as organic matter decomposition, nutrient transformation and most importantly plant-microbe interactions. Extensive studies have been done on the microbial diversity, but there are limited reports on the molecular determinants regulating microbial adaptability and efficiency in soil environments. Peptidyl-prolyl cis/trans isomerases (PPIases) are conserved enzymes that catalyze protein conformation which is essential for protein folding and functions. This study discusses the current knowledge on the occurrence and functional role of parvulin-type PPIases in soil microorganisms and plants. These enzymes are involved in diverse cellular processes, including cell wall biogenesis, cell cycle progression, stress tolerance etc. Such functions enhance microbial survival and activity, thereby can indirectly influence soil fertility and ecosystem processes. Therefore, integration of these molecular insights highlights parvulins as potential indirect modulators of soil health. Further understanding of their roles may provide new perspectives for enhancing microbial performance and developing sustainable strategies for soil fertility management.

Introduction
Soil fertility is a fundamental component of sustainable agricultural practices (Powlson *et al.,* 2011), impacting crop productivity, food security, and environmental well-being (Montgomery, 2017). It is governed by the interaction of biological, chemical and physical components of soil ecosystem. Among these, soil microorganisms play the most important role in nutrient cycling, decomposition and maintenance of soil structures (Yadav *et al.,* 2021). However, human activities such as excessive use of chemicals, deforestation, and climate have negatively impacted soil fertility and microbial biodiversity (Pahalvi *et al.,* 2021). Therefore, maintaining a healthy soil microbiome which are capable in nitrogen fixation, phosphate solubilization and other nutrient transformation is essential for sustainable soil health and ecosystem stability.
Peptidyl prolyl *cis/trans* isomerases (PPIase) catalyze the reversible *cis/trans* isomerization of peptide bonds at proline residues, facilitating proper protein folding and function (Alcock *et al.,* 2008). Based on substrate specificity, PPIase are of four sub families: Cyclophilins, FKBP (FK-506 binding proteins), Parvulins, and PTPA (protein phosphatase 2A activator) (Agbavor *et al.,* 2025). Among these, parvulins are the most unique PPIases recognizing both phosphorylated and unphosphorylated substrates (Rahfeld *et al.,* 1994). They are conserved across species ranging from lower organisms to humans and are implicated in protein folding, assembly, cell proliferation, gene regulation and signalling pathways.
The identification of parvulins in some soil microorganisms and plants provides new insights into how intracellular regulatory proteins may influence broader ecological processes. This aims to explore the importance of parvulins in different soil microbiome that directly or indirectly contribute to soil fertility and ecosystem functioning.

Parvulin in Soil Microbiome
Parvulin-type PPIases are widely distributed among soil microbiome including bacteria, fungi and other lower organisms (Figure 1). It plays an indirect important role in maintaining soil fertility by mediating the microbial survival and activity under diverse environment conditions.

Bacillus subtilis
B. subtilis is a well-known soil bacterium for enhancing nutrient absorption through the prevention of excess soil sodium accumulation and promoting bacterial diversity (Xia *et al.,* 2025). It is recognized as a plant growth-promoting rhizobacterium (PGPR), contributing to improve drought resistance and tolerance to saline-alkali conditions (Ding *et al.,* 2023). In *B. subtilis,* cell wall synthesis is reported to be mediated by the parvulin homolog, PrsA activity, facilitating proper folding and maturation of Penicillin Binding Proteins (PBPs) which are crucial for maintaining cell wall integrity (Hyyrylainen *et al.,* 2010). As such, this function is important for bacterial survival, it becomes important to further understand the role of parvulin in soil bacteria to improve plant growth and soil health.

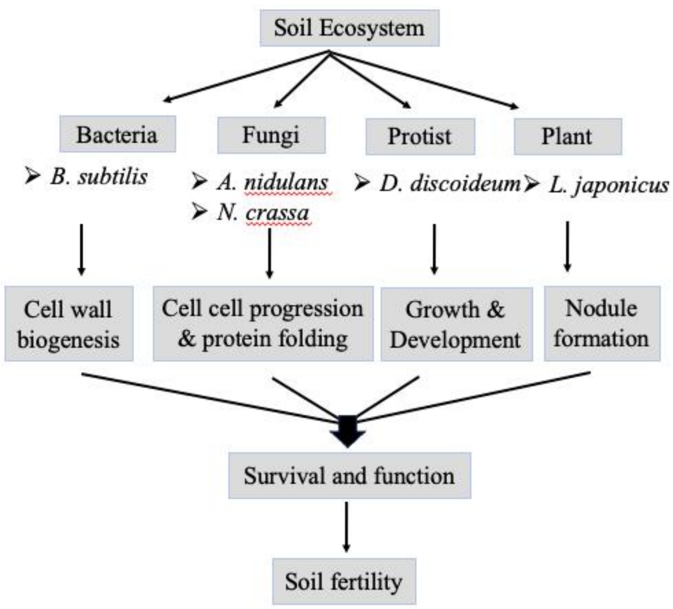

Figure 1: Shematic representation of the functional role of parvulin-type PPIases in different soil microorganisms and plant. Parvulin regulate protein conformation and cellular processes such as cell- wall biogenesis (*B. subtilis*), cell cycle progression (*A. nidulans),* protein folding *(N. crassa*), growth and development (*D. discoideum*) and nodule formation (*L. japonicus).* These enhances microbial survival and plant-microbe interaction contributing to soil fertility.

Aspergillus nidulans
A. nidulans is a soil-dwelling fungus with potential bioremediation to decompose organic matter and remove heavy metal such as arsenic from contaminated soil. (Maheswari and Murugesan, 2009). High concentration of heavy metals

in soils is associated with toxicity to biological organisms posing serious threat to plant growth and soil health, it is essential to maintain overall ecosystem. Therefore, for maintaining the soil ecosystem, proper growth and development of *A. nidulans* population becomes important. Parvulin-type PPIases particularly Pina, play a key role in regulating the cell cycle progression in *A. nidulans.* Depletion of PinA results in the lengthening of G1 phase, indicating its importance in normal cellular processes (Joseph *et al.,* 2004). Therefore, sustaining fungal growth under stress environment can contribute to soil ecosystem stability.

Neurospora crassa

N. crassa is a filamentous fungus that contributes to plant growth and soil fertility by stimulating root elongation and organic matters decomposition. It promotes nutrient recycling and support sustainable farming practice. At the molecular level, the presence of parvulin homolog, Ssp1 helps in maintaining cellular function of *N. crassa.* Ssp1 contains a unique polyglutamine stretch between the WW domain and the catalytic PPIase domain. It exhibits high protein-folding activity comparable to mitochondrial chaperones (Kops *et al.,* 1998). Thus, by ensuring the proper protein folding and stability, it supports *N. crassa* to thrive in soil habitat contributing directly to soil health.

Dictyostelium discoideum

D. discoideum is a soil-dwelling amoeba with a distinct life cycle of unicellular and multicellular stages. It plays a significant role in soil ecosystem by regulating nutrient cycling and soil fertility through bacterial consumption as a food sources (Kessin, 2001; Shingnaisui and Naorem, 2025). Parvulin-type of PPIases identified in *D. discoideum* are involved in both growth and development pathways (Haokip and Naorem, 2017). Thus, parvulins indirectly influence microbial dynamics and nutrient recycling supporting soil fertility.

Parvulin in plants (*Lotus japonicus)*

Parvulin-type PPIases are also present in plants that directly contribute to crop production and indirectly regulate soil ecosystem and health (Figure 1). *Lotus japonicus* is a leguminous plant known for its ability to establish symbiotic nitrogen fixation, that enhances soil fertility and crop productivity (Anderson and Stougaard, 2022). During nodule development in *L. japonicus,* the parvulin homolog, LjPar1, is significantly upregulated, suggesting its involvement in nodule formation (Kouri *et al.,* 2009). Since nodules are essential for nitrogen fixation, LjPar1 may likely contributes to this process through its protein folding activity. This suggests a direct link of parvulin in maintaining soil fertility.

Discussion

Parvulin-type PPIases are a conserved enzymes that plays key roles in intracellular protein regulation and soil ecosystem functioning. Numerous studies have reported that by catalazing protein conformation, it contributes to cellular processes such as cell-wall biogenesis (Hyyrylainen *et al.,* 2010), cell cycle progression (Joseph *et al.,* 2004) and the growth and development of soil microorganisms (Haokip and Naorem, 2017) and nodule development in plants (Kouri *et al.,* 2009). Given the importance of microbial activity and plant-microbe interaction in nutrient recycling, parvulin may indirectly contribute to maintaining soil fertility by enhancing microbial survival and functions.

Conclusion

Parvulin-type peptidyl-prolyl cis/trans isomerases (PPIases) are emerging as important molecular regulators that indirectly influence soil fertility through their role in protein folding and cellular function. Present across diverse soil microorganisms and plants, parvulins support essential processes such as cell wall biogenesis, cell cycle regulation, stress tolerance, and development. Despite this biological importance, studies on parvulins in soil ecosystem remain limited. Additionally, the regulatory and signalling pathways involving parvulin are not fully understood A deeper studies into the functional role of parvulin-type PPIase in more soil microbiome is a promising way to improve soil fertility in a sustainable manner.

REFERENCES:

1. Agbavor, C., M. Torres, N. L. Inniss, S. Latimer, G. Minasov, L. Shuvalova, Z. Wawrzak, D. Borek, Z. Otwinowski, P.J. Stogios and L.A. Cahoon, 2025. Structural analysis of extracellular ATP-independent chaperones of streptococcal species and protein substrate interactions. Msphere, **10**(2): e01078-24.
2. Alcock, F.H., J.G. Grossmann, I.E. Gentle, V.A. Likić, T. Lithgow and K. Tokatlidis, 2008. Conserved substrate binding by chaperones in the bacterial periplasm and the mitochondrial intermembrane space. Biochem. J. **409**(2): 377-387.
3. Andersen, S.U., and J. Stougaard, 2022. *Lotus japonicus.* Curr. Biol. **32**, R141–R157.
4. Ding, B., H. Cao, J. Zhang, Y. Bai, Z. He, S. Guo and H. Liu, 2023. Biofertilizer application improved cotton growth, nitrogen use efficiency, and yield in saline water drip-irrigated cotton fields in Xinjiang, China. Ind. Crop. Prod. **205**, 117553.
5. Haokip, N. and A. Naorem, 2017. Functional characterisation of parvulin-type peptidyl prolyl cis-trans isomerase, PinA in *Dictyostelium discoideum*. Biochem. Biophys. Res. Commun. **482**(2): 208-214.

6. Hyyryläinen, H.L., B.C. Marciniak, K. Dahncke, M. Pietiäinen, P. Courtin, M. Vitikainen, R. Seppala, A. Otto, D. Becher, M.P. Chapot-Chartier and O.P. Kuipers, 2010. Penicillin-binding protein folding is dependent on the PrsA peptidyl-prolyl cis-trans isomerase in *Bacillus subtilis*. Mol. Microbiol. **77**(1): 108-127.
7. Joseph, J.D., S.N. Daigle and A.R. Means, 2004. PINA is essential for growth and positively influences NIMA function in *Aspergillus nidulans*. J. Biol. Chem. **279**(31): 32373-32384.
8. Kessin, R.H. 2001. *Dictyostelium:* evolution, cell biology, and the development of multicellularity, **38**. Cambridge University Press.
9. Kops, O., C. Eckerskorn, S. Hottenrott, G. Fischer, H. Mi and M. Tropschug, 1998. Ssp1, a site-specific parvulin homolog from *Neurospora crassa* active in protein folding. J. oil. Chemistry, **273**(48): 31971-31976.
10. Kouri, E.D., N.E. Labrou, S.D. Garbis, Kalliampakou, K.I., Stedel, C., Dimou, M., Udvardi, M.K., Katinakis, P. and E. Flemetakis, 2009. Molecular and biochemical characterization of the parvulin-type PPIases in *Lotus japonicus*. Plant Physiol. **150**(3): 1160-1173.
11. Maheswari, S., and A.G. Murugesan, 2009. Remediation of arsenic in soil by *Aspergillus nidulans* isolated from an arsenic-contaminated site. Environ. Technol. **30**(9): 921-926.
12. Montgomery, D. R., 2017. Growing a revolution: bringing our soil back to life. WW Norton and Company.
13. Pahalvi, H. N., L. Rafiya, S. Rashid, B. Nisar and A.N. Kamili, 2021. Chemical fertilizers and their impact on soil health. In Microbiota and biofertilizers, Vol **2**: Ecofriendly tools for reclamation of degraded soil environs (pp. 1-20). Cham: Springer International Publishing.
14. Powlson, D.S., P.J. Gregory, W.R. Whalley, J.N. Quinton, D.W. Hopkins, A.P. Whitmore, P.R. Hirsch, and K.W. Goulding, 2011. Soil management in relation to sustainable agriculture and ecosystem services. Food Pol. **36**, S72-S87.
15. Rahfeld, J. U., K.P. Rücknagel, B. Schelbert, B. Ludwig, J. Hacker, K. Mann and G. Fischer, 1994. Confirmation of the existence of a third family among peptidyl-prolyl cis/trans isomerases Amino acid sequence and recombinant production of parvulin. FEBS letters, **352**(2), 180-184.
16. Shingnaisui, K., and A. Naorem , 2025. In silico analysis of Pin4, parvulin-type PPIase from soil amoeba *(Dictyostelium discoideum).* J. Soils and Crops **35**(2) 295-299.
17. Xia, H., H. Liu, P. Gong, P. Li, Q. Xu, Q. Zhang, M. Sun, Q. Meng, F. Ye and W. Yin, 2025. Study of the mechanism by which *Bacillus subtilis* improves the soil bacterial community environment in severely saline-alkali cotton fields. Sci. Total Environ. **958**, 178000.
18. Yadav, A., and K. Yadav, 2024. Challenges and opportunities in biofertilizer commercialization. SVOA Microbiol. **5**(1), 1-14.