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Review Article

Agricultural Applications of *Penicillium Genera*

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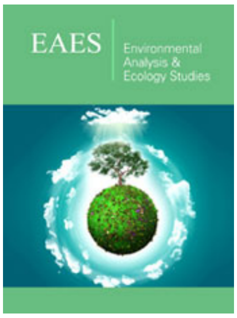

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Abstract

Penicillium genera are one of the well-known fungi present in many environments since saline soils to artic environments which makes them a microorganism of great interest for different investigations. These microorganisms have been widely studied for food and pharmaceutical applications; However, in recent years it has been seen that these species could have an importance for agricultural applications. These applications include phosphate solubilizing capacity and endophytic properties, which making crops resistant to diseases and extreme environmental conditions; as well as promoting a better crop development. Also, Penicillium species could degrade different xenobiotic compounds like pesticides, phenol, pyrene, crude oil, between other; but a big amount of these researches were made in liquid medium, for that reason the soil applications are a very broad field of research for future investigations. All these characteristics makes the *Penicillium genera* an interesting topic for future investigations in agricultural and environmental applications.

Keywords: Penicillium; Agricultural application; Phosphate solubilization; Endophytic; Xenobiotic degradation

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Introduction

The genera Penicillium are one of the older, well-known and most common fungi that can develop in a diverse range of habitats like soil, air, indoor environments, and food [1]. These fungi are widely studied for its secondary metabolites production, capable of producing substance with important pharmaceutical applications like antimicrobial agents where its major apport was the production of penicillin [2]; but also, its metabolites could be used as immunosuppressants, cholesterol-lowering agents, anti-HIV and antitumor drugs [3]. Also, on food industry has a big importance to produce cheeses, like Camembert or Roquefort [4].

Penicillium species has been reported in many terrestrial environments; up to 200 species have been described in habited soils [5]; and many others have been found at rhizospheric level [6], so it is assumed that this ascomycete has an important role for agricultural applications. To study Penicillium species is also of great interest, because they can develop under extreme conditions, like 4 °C, pH ranges from 2 to 12 and salinity up to 20% w/w [7]; also, different species have been isolated from unconventional environments such as the Arctic, mines, and ocean sediments [3]. Given its versatile development are microorganism interesting to study, for environmental and agricultural applications.

Discussion

Phosphate solubilization

Probably the phosphates solubilization is the best known and most useful agricultural application of Penicillium species. Phosphorus is an element that promotes plant growth, and less than 10% of the phosphorus in the soil is available for the biogeochemical cycle [7]. This property has been associated with the segregation of organic acid's such as tricarboxylic, citric and oxalic, among others [8]. The function of these acids is the acidification of soils, allowing the availability of micronutrients, such as Fe, Zn and Mn.

The organic acid production has another importance, associated to microbial chemotaxis and metal detoxification [9], which represent another benefit to use Penicillium species in soil. A big amount of conventional fertilizers has traces of Cadmium [10] which is a heavy metal associated to Anemia, Kidney, Lung and Bone Damage; as well as Nervous Disorders and Cancer [11] so the use of solubilizing microorganisms instead of fertilizers shows an environmental and health impact, in order that is possible to reduce the periodicity of fertilization, as well as the concentration of these compounds. The above implications suggest that the use of Penicillium species instead of chemical fertilizers for its capacity of solubilize phosphorus, could be an interesting research topic for future investigations.

Endophytic fungus

Another important and useful application of the *Penicillium genera* is associated with its ability to act as an endophytic fungus in different crops, which involves [12]:

A. Greater access to nutrients to the crop.

B. Protection against extreme conditions.

C. Protection against insects, parasites, and other microbes.

Protection against pathogen organism: The resistance to insects and other organism happens when crops are expose to Penicillium species. It generates a type of resistance to pathogens, which is known as a Systematic Acquired Resistance (SAR), when it happens the crop activates different enzymes (Chitinases, Glucanases, Peroxidases, Oxidases and Lyases), metabolites (Salicylic and Jasmonic Acids) and phenolic compounds as a defense mechanism which protect them from attacks of pathogenic organisms [13].

There are some works related to pathogen resistance of crops when were in contact with different species of the genera Penicillium, Table 1 present one of these investigations. Another action mechanism of Penicillium species as protection of pathogen organism, is related to secondary metabolites production like penintrems. An example of this, is the penintrem A production by *P. crustosum* that showed a 100% reduction in adults of milkweed inche (Oncopeltus fasciatus); as well as penintrem C which showed a reduction of 73.3% for the same organism, and 100% for adult fruit flies (Ceratitis capitata) at a dose of 10µg/fly [18]. All these results shows that the application of Penicillium species, as a biological control instead of chemical, make a healthier and ecofriendly crop production.

Table 1: Protection of different Penicillium species against pathogen organism in different plants.

Penicillium species	Plant	Action	Reference
Penicillium simplicissimum	*Arabidopsis thaliana Nicotiana tabacum*	Resistance against cucumber mosaic virus	[14]
P. simplicissimum	*A. thaliana*	46% reduction in proliferation of Pseudomonas *syringae bacteria*	[15]
Penicillium sp.	*Cucumis sativus*	65.6% resistant to Colletotrihum orbiculare 52% resistant to P. *syringae pv. Lachrimans*	[13]
P. chrysogenum	*A. thaliana Lycopersicon esculentum*	93% resistant to Hyaloperonospora parasitica 50% resistant to Botrytis cinérea	[16]
P. chrysogenum	*Vitis vinifera*	88% resistant to Plasmopara vitícola 93% resistant to Uncinula necátor	[17]

Crop improvement: As was mentioned in section 4.2, endophytic fungi also providing greater access of soils nutrients and this, together with the secretion of hormones, is reflected in a better crop development; Table 2 shows some examples of this behavior. These results, together with the phosphate solubilizing capacity mentioned before, make the use of *Penicillium genera* as a biofertilizer of great interest for the development of organic crops [19-22].

Table 2: Crop improvement by different Penicillium species.

Penicillium species	Plant	Effect	Reference
P. simplicissimum	*A. thaliana*	Twice dry and fresh weight.	[14]
	N. tabacum		
	N. benthamiana		
P. notatum	*Raphanus sativus var. longipinnatus*	Higher root length, dry and fresh weight.	[19]
Penicillium verruculosum	*Vigna radiata Cicer arietinum*	Twice root length	[20]
P. crustosum	*Phaseolus leptostachyus*	Higher germination index Three times more root weight 1.5 more aerial weight	[21]

Degradation of xenobiotic compounds

Another application of great interest is related to the capacity of Penicillium species to degrade different xenobiotic compounds; this behavior is associated to the productions of reactive oxygen species which oxidate the compound [22] in one less toxic, and in some cases the complete mineralization (CO2 and water). A big amount of these researches were made in liquid medium, but there are some works in soil systems that are present in Table 3. The fact that Penicillium species can be used as biofertilizers, but also have the ability to biodegrade xenobiotic compounds, makes them a microorganisms of highly important for agricultural applications, which have not been fully study [23-28].

Table 3: Penicillium species for degradation of different xenobiotics in soil.

Penicillium species	Degradation rate (%)	Xenobiotic compound	Time (days)	Reference
Penicillium sp.	80	Endosulfan	30	[23]
Penicillium frequentans	90.8	Endosulfan	15	[24]
P. crustosum	93	Endosulfan	30	[25]
Penicillium sp.	60	Phenol	30	[26]
Penicillium sp. SFU 213	95	Pyrene	14	[27]
Penicillium Chrysogenum	61.62	Crude oil	28	[28]

Conclusion

Given the excessive use of agrochemicals, looking to stop pests, and increasing soil fertility, in recent years, we are consumed vegetables of low nutritional and health qualities; as was previously discuss an alternative to improve crop development and make them resistant to diseases and extreme environmental conditions could be the use of Penicillium species. These genera can also, biodegraded different xenobiotics compounds like pesticides, phenol, pyrene, crude oil, between other, which makes these microorganisms interesting species to study for future environmental and agricultural investigations.

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