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Asian Agricultural Research 2023, 15 (5): 41 – 43 DOI: 10.19601/j.cnki.issn1943 – 9903.2023.05.010

Research Progress in Biological Control of Soft Rot of *Amorphophallus konjac*

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Abstract In this paper, the main control methods of soft rot of *Amorphophallus konjac* are reviewed, with a focus on the current research status of using plant growth promoting rhizobacteria for biological control of soft rot of *A. konjac*, and future research directions are looked forward to.

Key words *Amorphophallus konjac*, Soft rot, Plant growth promoting rhizobacteria, Induced resistance

1 Introduction

Amorphophallus konjac is perennial herb of *Amorphophallus* of Araceae, and could synthesize large amounts of konjac glucomannan (KGM). Due to strong thickening and film-forming properties, KGM is widely used in industries such as food, health products, pharmaceuticals, cosmetics, and chemicals, and has broad development prospects[1–2]. Yunnan Province is the birthplace of *A. konjac* in China, and the *A. konjac* industry is also one of the important pillar industries for agricultural industrial structure adjustment and farmers' poverty alleviation and prosperity in the central and western regions[3]. Soft rot of *A. konjac* is a bacterial disease mainly caused by *Erwinia carotovora* subsp. *carotovora* (Ecc.)[4]. It generally occurs in the production of *A. konjac*, and the resulting yield loss can reach 20% to 50%. Therefore, soft rot is often referred to as the "cancer" of *A. konjac*, and its high incidence has become the main factor limiting the development of *A. konjac* industry[5]. Exploring efficient prevention and control methods for soft rot of *A. konjac* is a necessary means to promote the development of *A. konjac* industry.

2 Prevention and control methods of soft rot of *A. konjac*

The research on the prevention and control of soft rot of *A. konjac* is currently mainly focused on the selection of resistant varieties and genetic engineering, chemical control, biological control, and other aspects. The breeding of resistant varieties of *A. konjac* has always been one of the research hotspots in the prevention and control of soft rot. *A. konjac* is mainly distributed in the southern region of the Qinling Mountains in China, and *A. konjac* species resources in the southwestern and southern regions of Yunnan are the most abundant, and there are 16 species of recorded wild *A. konjac*[6]. At present, the main cultivated varieties after artificial breeding include *Amorphophallus konjac* K. Koch, *Amorphophallus albus* P. Y. Liu & J. F. Chen, *Amorphophallus krausei* Engler, *Amorphophallus yunnanensis* Engl., *Amorphophallus muelleri*, *etc*[7–9]. Among them, *Amorphophallus bulbifer* (Roxb.) Blume, represented by *A. muelleri*, has received a lot of attention in recent years due to its excellent resistance to soft rot of *A. konjac*. *A. bulbifer* (Roxb.) Blume has also become one of the research hotspots in variety breeding[9]. Although some progress has been made in disease resistance breeding, *A. konjac* K. Koch is still the most widely planted species in China at present. Therefore, the current focus of prevention and control of soft rot of *A. konjac* is to extensively collect germplasm resources for research and promotion, and to comprehensively select economically valuable resistant *A. konjac* varieties through various breeding methods. Additionally, further development of preparations with good control effects on soft rot of *A. konjac* is needed to control the impact caused by the disease. At present, chemical agents such as streptomycin, thiamazone, clotrimacin, bromobinil, *etc.* are mainly used in production to control the soft rot of *A. konjac*, which can control the development of the soft rot of *A. konjac* to a certain extent[10–11]. However, long-term use of chemical agents not only enhances bacterial resistance, but also causes adverse effects such as pesticide residues in agricultural products and damage to the ecological environment. With the development demand of green agriculture and the improvement of people's awareness of food quality and safety, researchers have conducted biological control of soft rot of *A. konjac* by screening and using beneficial microorganisms and their metabolites, plant extracts, *etc.* that can antagonize the pathogen of soft rot of *A. konjac* in recent years.

Received: March 3, 2023 Accepted: May 7, 2023
Supported by Joint Special Project for Basic Research of Local Undergraduate Universities in Yunnan Province (202101BA070001-057); 2021 Provincial College Student Innovation and Entrepreneurship Training Program Project in Yunnan Province (202111393018); Science Research Fund Project of Yunnan Provincial Department of Education (2022Y705, 2023Y0857, 2023Y0859).
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3 Biological control of soft rot of *A. konjac*

3.1 Current situation of biological control At present, there is a lot of research on inhibitory effects of biocontrol bacteria such as *Lysobacter*[12-14] and *Bacillus subtilis*[15-18], biocontrol actinomycetes such as streptomyces[19-21] on soft rot of *A. konjac*, and antibacterial activity of plant extracts such as water extract from *Melia azedarach* leaves and seeds against Ecc. Among them, screening biocontrol bacteria that resist the pathogen of soft rot of *A. konjac* is currently a research hotspot, and certain research progress has been made. But there are still many limitations in application and promotion. Many studies have reported biocontrol bacteria that have good inhibitory effects on soft rot of *A. konjac*, but the types of microbial agents available for resisting soft rot in practical production applications are still relatively limited, and the screening of antagonistic microorganisms needs to be further strengthened. From the current research, it can be seen that no particularly effective biological control methods have been found. Currently, production mainly relies on chemical agents combining with agricultural measures to prevent and control the soft rot of *A. konjac*.

3.2 Using plant growth promoting rhizobacteria to control soft rot of *A. konjac* Plant growth promoting rhizobacteria (PGPR) is a rhizosphere microorganism that can directly or indirectly promote plant growth. During the interaction with plants, some PGPRs can stimulate the production of system signals, trigger defense responses in the distal region, and ultimately form resistance throughout the entire plant. They exhibit rapid and strong resistance to subsequent pathogen infections, known as systemic resistance, also known as induced resistance[23-24]. The plant induced resistance is persistence and broad-spectrum. Once induced, resistance can last for weeks or even months, and can resist various pathogens with different life histories and invasion strategies[25]. With the continuous application of induced resistance in plant disease control and the further study of its mechanism, the use of induced disease resistance of plants has become a research hotspot in the field of plant disease control. Research by Zhang Zhongliang *et al.* showed that root irrigation with LouChe's streptomyces D74 bio organic fertilizer can enhance the polyphenol oxidase activity and soluble protein content of *A. konjac*, and enhance the disease resistance of *A. konjac*[26]. Lei Zhenzhen *et al.* studied the changes in SA and JA content in leaves of *A. konjac* K. Koch plants resistant to soft rot and common susceptible plants after inoculation with soft rot pathogens. They found that the changes in SA and JA content in leaves of *A. konjac* K. Koch plants with strong resistance were significantly different from those of ordinary plants after inoculation with soft rot pathogens[27]. It can be seen that using PGPRs with antibacterial effects on the pathogenic bacteria of soft rot of *A. konjac* for comprehensive control could inhibit the growth of the pathogenic bacteria, and regulate the rhizosphere microenvironment. Additionally, it could induce the disease resistance of *A. konjac* plant system, enhance the plant's resistance to the pathogenic bacteria of soft rot, which is a new way to prevent and control soft rot of *A. konjac*. However, there are currently few reports on this aspect of *A. konjac*.

The induced resistance of plants is divided into systemic acquired resistance (SAR) and induced systemic resistance (ISR). SAR is generally induced by pathogenic microorganisms and chemical inducers such as salicylic acid (SA) and 2,1,3-benzothiodiazole (BTH), depends on SA mediated signaling pathways, and is marked by the expression of a large number of pathogenesis-related protein genes[28]. ISR is generally induced by plant rhizosphere promoting microorganisms, such as plant growth promoting rhizobacteria (PGPR), and depends on jasmonic acid (JA)/ethylene (ET) mediated signaling pathways[29]. Different from SAR, the formation of ISR is not accompanied by a direct disease resistance defense response, but rather by a faster defense response when plants are attacked by pathogens, a phenomenon known as priming[30-31]. There have been reports that PGPR and its metabolites can induce plant resistance to soft rot pathogens. The two strains of *Pseudomonas* isolated from potato tubers by Pavlo *et al.* not only promote growth of potato plants, but also induce systemic resistance of plants. SAR and ISR marker genes are expressed to varying degrees[32]. Streptomyces PM1 and PM5 (PGPRs) not only have antibacterial effects on Ecc., but also can stimulate plant immune response and induce rapid accumulation of polyphenol oxidase and peroxidase in plants[33]. The research by Chandrasekaran *et al.* showed that inoculation with *Bacillus subtilis* CBR05 (PGPR) can enhance the resistance of tomatoes to *Ecc.* Among them, the expression of disease-resistant genes and the activity of antioxidant enzymes induced by *B. subtilis* system play a key role in the resistance to soft rot[34].

4 Prospect

Although there have been few reports on the use of induced resistance to control soft rot of *A. konjac*, the use of PGPR, which has the ability to induce systemic resistance of plants, to control Ecc. can provide a reference for the control of soft rot of *A. konjac*. It is a new way to prevent and control soft rot of *A. konjac* using rhizosphere microorganisms that have antibacterial effects.

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