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BIOCONTROL OF MAIN DISEASES AND ADVANCE IN ANTIFUNGAL MECHANISM OF STREPTOMYCES SPP. IN WHEAT

Wheat is one of the main cereal crops in the world, and it is the source of staple food for more than 40% of the world's population. Countries, exceeding 10 million tons of the total output, involve the United States, China, India, Canada, Australia and so on. Therefore, wheat plays an important role in the world's cereal crops. However, the production of wheat fluctuates every year. Wheat diseases are one of the primary factors which affect the yield and quality of wheat. The main diseases of wheat in China are Head Blight (caused by *Fusarium graminearum*), Sharp Eyespot (caused by *Rhizoctonia cerealis*), Take-all (caused by *Gaeumannomyces graminis*), Powdery mildew (caused by *Blumeria graminis* f. sp. *tritici*) and so on. As we enter the era of biologically sustainable agriculture, comparing with the traditional chemical control methods, the biocontrol becomes a promising way for disease prevention.

Biocontrol of wheat diseases is mainly based on microorganisms or the secondary metabolites produced by them. Firstly, the biocontrol agents of microorganisms are fungi, bacteria and actinomycetes. At present, there are few species of fungi for biocontrol of wheat diseases. Commercial biocontrol agents are mainly *Trichoderma harzianum* and fewer *Trichoderma viride* strains. They can control leaf rust. Gram-negative bacteria are the most commonly used biocontrol agents, such as *Pseudomonas* spp., *Agrobacterium radiobacter*, *Bacillus* spp. and *Erwinia* spp. *Bacillus subtilis* shows good biocontrol effect on Wheat Head Blight

and Wheat Sharp Eyespot. Secondly, different biological preparations are produced on the basis of antibiotics of microorganisms. The following antibiotics are used to protect wheat against disease: polyoxin is mainly used to control Powdery Mildew and Sharp Eyespot; pyrimidine nucleoside antibiotics - mainly Wheat Rust, Sharp Eyespot and Powdery Mildew; validamycin plus Bacillus cereus - mainly Head Blight; trichodermin and validamycin – mainly Sharp Eyespot; ningnanmycin (made in China) – mainly Powdery Mildew.

Among all microorganisms *Streptomyces* spp. are the most attractive microorganisms for the active secondary metabolites. More and more Streptomyces spp. resources have been found and studied. *Streptomyces* 12-09-4 and 12-09-11 showed strong protective effects (> 70 %) on wheat powdery mildew. The *Streptosporangium becharense* strain SG1 exhibited remarkable protective effect by

all seed treatments, which reduced the disease severity index from 77,8 % to 16 %, whereas it was only reduced to 24,2 % by chemical seed treatment with Dividend (R). In field trials, strains, EN23, and EN27 were effective in suppressing fungal root diseases of wheat when added as spore coatings to wheat seed. *Streptomyces mutabilis* strain, named IA1, reduced both disease occurrence (64,7 %) and decrease severity (79,6 %), which was caused by *Fusarium culmorum* on seedlings.

The research on biocontrol of Streptomyces spp. mainly focused on finding the new strains and the antifungal activity of them. There were few reports on the antifungal mechanism of *Streptomyces* spp. against wheat diseases. Compared with other cereal crops, the main mechanisms of Streptomyces spp. are competition for nutrition, inducing plant resistance and antagonism.

There is competition for nutrition and living space between biocontrol bacteria and pathogens. Competitive biocontrol bacteria have strong adaptability to the environment and fast growth. They can effectively use low concentration nutrients on the plant surface or near the invasion point to quickly occupy the space and absorb nutrients.

Induced systemic resistance (ISR) emerged as an important mechanism by which selected plant growth-promoting bacteria and fungi in the rhizosphere prime the whole plant body for enhanced defense against a broad range of pathogens. Induction of systemic resistance can increase the activity of pathogen-related proteins (PR-proteins) related to plant defense, such as: chitinase, β-1,3 glucanase, superoxide dismutase and so on.

The targets of antagonistic mechanism mainly involve the following aspects:

1) Acting on the cell wall of pathogen (according to the related research reports, the MHCE0811 produced the maximum chitinase which probably degraded the fungal cell wall and limited growth of test fungal pathogens.

2) Acting on the cell membrane of pathogen (pimaricin selectively binds to ergosterol in fungal cell membranes, causing changes in cell membrane permeability, leakage of intracellular substances and cell death.

3) Acting on the energy metabolism system. Streptomyces spp. strain SM8, isolated from *Haliclona simulans*, possessed antifungal and antibacterial activities and inhibits the calcineurin pathway in yeast.

4) Acting on protein synthesis system. For example, streptomycin acted on the whole process of protein synthesis.

Further exploring functional genes of Streptomyces spp. will helpful for the application of Streptomyces spp. as biological control agents in the future of agriculture. However, there were few reports on the functional genes of Streptomyces spp. in wheat diseases. According to the related reports, sequencing of the S8 strain genome revealed a valinomycin biosynthesis gene cluster. This cluster is composed of the vlm1 and vlm2 genes, which were known to produce antifungal compounds. In

order to verify this finding for the large pathogen (*Rhizoctonia solani* AG2-2), a valinomycin biosynthesis knockout mutant was created via the CRISPR/Cas9 system. The mutant lost antifungal activity against the large patch pathogen. Two bacteria, *Streptomyces albireticuli* MDJK11 and *S. alboflavus* MDJK44, which were potential plant growth-promoting rhizobacteria against pathogenic fungi were isolated from the rhizosphere soil of peony in Shandong, China. Their biological characteristics and complete genome sequences were reported in this study. Gene or gene cluster candidates responding to secondary metabolites production were also analyzed.

With the discovery of more and more new *Streptomyces* spp. strains and the prominent antifungal activity of their metabolites, the application of more potential biocontrol agents has become the focus of scientific research. However, we also found that the mechanism of many biocontrol agents is still not known. For example, the parasitic and antagonistic effects of biocontrol bacteria make it difficult to reveal the mechanism of action because of its special mode of action. With the resistance promoting of pathogen and the emergence of new diseases, it is an urgent task to find new antibiotics.