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Comprehensive Management Strategies for Controlling Potato Scab in Taiwan: Prevention, Cultural Practices, and Biological Control

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ABSTRACT

Potato scab, caused by Streptomyces spp., poses a significant threat to global potato production, including in Taiwan where cultivation began in 1914. Although historically rare in the region, the disease has increasingly been problematic, particularly after a severe outbreak in 1995. This review synthesizes research on the etiology, transmission, and management of potato scab, highlighting its detrimental effects on yield and quality. Streptomyces spp., the primary pathogens persist in soil and infect tubers primarily through wounds or lenticels. Environmental factors such as moisture and pH play a critical role in disease severity. Preventive strategies including soil flooding, crop rotation with rice, and the use of certified seed potatoes have proven effective. Additionally, advancements in biological control, such as the application of Bacillus subtilis LNP-1, showing promising potential for sustainable management. Integrating these strategies into potato production management can mitigate the impact of potato scab, ensuring yields and quality.

Keywords: *Streptomyces* spp., soil moisture, crop rotation, rice, healthy seed potatoes, Taiwan

MANAGEMENT STRATEGIES FOR CONTROLLING POTATO SCAB

Potato (*Solanum tuberosum* L.) is an annual Solanaceous crop and ranks as the fourth largest food crop in the world, following rice, corn, and wheat. Potato cultivation in Taiwan began in 1914. According to the 2023 Agricultural Statistics Annual Report, its planting area has reached 2,744 hectares, with a total yield of 62,106 metric tons. The potato production is mainly concentrated in Taichung City, Yunlin County, and Chiayi County. The yield of potato is approximately 22.6 metric tons per hectare (https://agrstat.moa.gov.tw/sdweb/public/book/Book.aspx). The main cultivated varieties are Kennebec, Atlantic, and Omega (Chan *et al*., 2011). In the past, potato scab rarely occurred in Taiwan, but in the winter of 1995, severe outbreaks of the disease were first documented in the potato-growing areas of Tanzi, Taichung City, and Dounan, Yunlin County (Huang, 2008). Later, this disease is getting worse year by year.

Potato common scab, caused by *Streptomyces scabiei* (syn. *Streptomyces scabies*) and related species, poses a threat to potatoes in various production areas worldwide (Lankau *et al*., 2020; Liu *et al*., 2021). The affected parts of the potatoes exhibit corky, rough, and bulging characteristics, make infected potato without commercial value (see Figure 1). Besides potatoes, the potato scab pathogens can infect a variety of root and tuber crops such as radish, beet, carrot, and sweet potato (Goyer *et al*., 1998). Since it directly affects the harvested parts, severe cases can lead to significant crop damage, resulting in substantial impacts on yield and quality. The primary known pathogens causing potato scab include by different strains, *S. acidiscabies*, and *S. turgidiscabies* etc. (Liu *et al*., 2021; Lambert and Loria, 1989a, b; Miyajima *et al*., 1998; Wu, 2020). The potato scab may be caused by a single *Streptomyces* sp. or complex infection with various *Streptomyces* spp. with various symptoms.

Figure 1. Symptoms of potato scab: Brown spots formed on the affected areas, with a sunken center and raised edges. The texture is corky and scab-like.

The potato scab pathogens can persist on diseased potatoes or survive saprophytically in the soil, utilizing spores as its primary inoculum source of infection. The pathogens are spread from one location to another by splashing water (irrigation or rain) and wind, and on infected seed tubers and farm equipment with leftover soil residue (Wharton *et al*., 2007). These pathogens can infect potato at various growing stages through lenticels or wounds. Infected areas appear brown spot symptom with a central depression and raised edges, exhibiting a corky, scab-like texture that easily breaks. Three major types of lesions are superficial lesions, raised lesions and pitted lesions (Loria et *al*., 1997). The scab pathogens can survive in the soil for several years. Upon encountering the roots, the pathogens infect the plant and colonize the root system, inducing the formation of nodules. As potato plants mature, the scab pathogen can spread from the roots to the developing tubers. The pathogen can generate a mucus layer to adhere to the tuber's surface and produce enzymes that decompose the potato tuber's cell wall, resulting in ridges or depressions of various sizes on its surface (Larkin and Griffin, 2007). The time suitable for infection depends on several factors, including the abundance of scab pathogens in the soil, the susceptibility of potato varieties, and the environmental conditions during the growing season, particularly temperature and moisture levels (Larkin and Griffin, 2007).

In winter, potato is one of the main crops of rice rotation in Taiwan. Therefore, Chung (2009) investigated the survival of potato scab pathogen in the soil following rice cultivation. Soil from severely *Streptomyces* spp. infected potato fields with two year's potato production was transferred to pots in greenhouse. When potatoes were planted in these pots, tuber disease still developed, though with a relatively low incidence (21.3%) and mild severity (5.6%). Chung (2009) also observed that flooding the field area to a depth of 4 cm above the soil resulted in an 86% reduction in the population of scab pathogens in the soil after 8 weeks of flooding. The application of rice rotation can reduce the population of scab pathogens in soil.

Tsai *et al.* (2002) revealed that the organic matter content in loam soil in the Dounan, Yunlin County is positively correlated with the disease severity of potato scab. Furthermore, their findings indicated that maintaining the moisture content of the cultivation medium in pot test at 12-20% resulted in 100% disease severity of potato scab; whereas, when humid condition maintained at 33-40%, the disease severity of potato scab decreased to 70.8%, with the control group, not inoculated with the pathogen, showing 0% disease severity. Additionally, flooding induces an anaerobic status in the soil, reducing oxygen supply to plant roots and fostering the growth of anaerobic bacteria that produce toxic compounds harmful to the roots of potato plants. Flooding also increases soil pH and decreases the availability of essential nutrients such as iron and manganese necessary for growth and development of potato plants. These factors can hinder potato growth, therefore induce potato more susceptible to various plant pathogens. Hence, it is advisable to increase the frequency of irrigation to maintain field soil moisture during the period of potato tuber formation (Tsai *et al*., 2022). However, drastic alterations in field soil humidity or flooding should be avoided. This precautionary measure may serve as an effective farming strategy for preventing and controlling potato scab.

Researchers of Taiwan Seed Improvement and Propagation Station conducted a random sampling and survey of 20-100 tubers in potato fields in 2012. The tubers were classified based on the proportion of the potato scab infected area. Grade 0 indicated no infection; Grade 1 denoted an infected surface area comprising less than 1/3; Grade 2 represented a diseased area ratio ranging from 1/3 to 2/3; Grade 3 indicated a diseased area ratio exceeding 2/3. It was observed that the average grade of potato scab in fields utilizing healthy seed potatoes ranged from 0.04 to 0.63, whereas in control fields, it ranged from 0.24 to 0.83 (Yuan *et al*., 2014). These findings demonstrate that the utilization of healthy seed potatoes can effectively reduce the disease severity of potato scab. Therefore, employing healthy seed potatoes at the outset is a crucial measure in preventing potato scab.

Based on the life history and occurrence conditions of the potato scab pathogens, the following preventive measures can be implemented to mitigate the disease occurrences:

1. Soil flooding: According to Chung (2009), the field area was flooded to 4 cm above the soil. After 8 weeks of flooding, the number of potato scab pathogens in the field soil was reduced by 86%. Rotation with rice would have a better effect on reducing the population of potato scab pathogens. It is recommended that rice fields be used as the initial crop before planting potatoes.
2. Field sanitation: If potato scab occurs on potatoes grown in the early stage, diseased potatoes that have no commercial value should not be discarded in the field (Figure 2). If the field area is not flooded and rotated with rice or other non-host crops, the population of potato scab pathogens may increase year by year, therefore the severity of potato scab increases.
3. Healthy seed potatoes: Many diseases harm potatoes, such as early blight (*Alternaria solani*), late blight (*Phytophthora infestans*), bacterial wilt (*Ralstonia solanacearum*), bacterial soft rot (*Erwinia carotovora* subsp. *carotovora*), black scurf (*Rhizoctonia solani*), bacterial ring rot *(Clavibacter michiganensis* subsp. *sepedonicus)*, common scab (*Streptomyces scabiei* and related species), etc (Arora and Khurana, 2004; Arora and Sagar, 2014; Ranjan *et al.*, 2021). To prevent the spread of diseases through seed potatoes, the Animal and Plant Health Inspection Agency (APHIA), and the Taiwan Seed Improvement and Propagation Station (TSIPS), Ministry of Agriculture, are committed to cultivating healthy seed potatoes, establishing basic seed potatoes (G1), foundation seed potatoes (G2), stock seed potatoes (G3), and commercial seed potatoes (G4), four stages of propagation systems (Wu, 1994; Chen *et al*., 2022; MOA, 2023), and the healthy seed potatoes obtained by farmers are the "fifth generation (G5)", which can be used for the cultivation of edible potatoes. It is recommended that farmers use healthy seed potatoes from reputable and certified sources. Avoid planting seed potatoes that are infected or contaminated with potato scab pathogens as they can spread potato scab to the next field and infect surrounding healthy potato plants.
4. Disease-resistant varieties: Planting disease-resistant varieties is an effective way to control the common scab. Kennebec, currently cultivated on a large scale in Taiwan, was originally a scab-resistant variety but is now more susceptible to scab pathogens. Other varieties such as Pike, Red Norland, Russet Burbank, Shepody, Silverton, and Superior are resistant or tolerant varieties that can help to reduce the disease incidence of common scab, but they may not be effective in all growing conditions. Therefore, it is important to incorporate resistant varieties and implement other management practices for optimal control.
5. Soil Management: Soil pH and moisture content both affect the disease severity of potato scab (Braun *et al.,* 2017). Maintaining proper soil pH and moisture levels can help reduce the occurrence of this disease.
6. Fertilizer management: Avoid using high rates of nitrogen fertilizers as they increase susceptibility to potato scab (Tuncer, 2002). It is recommended to use balanced fertilizers which are low in nitrogen.
7. Chemical fungicides: At present, there is no registered fungicides recommended for preventing and control the potato scab in Taiwan.
8. Biological control: The principle of biological control is to use beneficial microorganisms to compete for nutrients or niches, hyperparasitism, and secrete antibiotics against pathogens, and/or induce disease resistance in crops to prevent the occurrence and spread of diseases. The research team of the Taiwan Agricultural Research Institute (TARI) has developed a new biocontrol agent "*Bacillus subtilis* LNP-1". Artificially infected seed potatoes are cut into pieces and coated with *B. subtilis* LNP-1 wettable powder (WP, 50-fold diluted) and then planted in the field. The seedlings

are then drenched with *B. subtilis* LNP-1 suspension concentrate (SC 400-fold diluted, for 8 times) after they emerge from soil. *B. subtilis* LNP-1 treatment reduces the disease severity by 63%. Seed coating treatment also reduces the disease severity of potato scab by 47%. In addition, if healthy seed potatoes measure combined with field sanitation measure from the last crop season in the field, the success rate of biological control will be improved.

Figure 2. Severe potato scab in field. Diseased potatoes are often discarded in the field, which become an inoculum source to the next potato production.

CONCLUSION

Potato scab, caused by various Streptomyces species, is a significant disease that threatens potato yield and quality, particularly in regions with favorable conditions such as Taiwan. Effective control strategies are essential to mitigate the disease's impact and safeguard crop production. Key management measures include soil flooding and crop rotation with rice to reduce pathogen populations, using certified disease-free seed potatoes, practicing field sanitation, selecting resistant varieties, managing soil pH and moisture, and applying balanced fertilizers. Additionally, biological control agents such as Bacillus subtilis LNP-1 have shown promising results when integrated with these practices, offering an environmentally sustainable approach to controlling potato scab.

Taiwan's agricultural policy, which aims to reduce pesticide risks by 50% from 2018 to 2027, directly supports the adoption of sustainable pest management strategies. This policy aligns well with the integration of biological control methods, which offer an alternative to chemical pesticides and contribute to long-term environmental health. The Taiwanese government's commitment to fostering sustainable agricultural practices is further reinforced by supportive measures such as financial incentives for farmers to adopt biological control agents and other eco-friendly pest management strategies. Regulatory frameworks that encourage reduced pesticide use and support for research into biological control methods are also critical to creating an enabling environment for these practices.

However, there are challenges that need to be addressed to ensure the broader adoption of biological control. These include the need for more education and awareness among farmers about the benefits of biological control agents, as well as overcoming potential resistance to shifting away from conventional pesticide-based practices. Strengthening policies that promote research, extension services, and farmer training will be crucial for the successful integration of biological control into Taiwan's pest management landscape. By addressing these challenges, Taiwan can create a more sustainable and resilient agricultural system that reduces dependence on chemical pesticides while improving the quality and yield of crops such as potatoes.

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AUTHORS' CONTRIBUTIONS

Tsung-Chun Lin contributed 50% to the work, Chiao-wen Huang 10%, Yi-Nian Chen 10%, Chun-Wei Chen 10%, and Jiun-Feng Su 20%.

COMPETING INTEREST

All the authors declare that there is no competing interest.