

I. INTRODUCTION

1.1. Background

Bird's eye chili (*Capsicum frutescens* L.) is an important horticultural crop with a relatively complete nutritional content and high economic value. In addition to household consumption, bird's eye chili is also used as a raw material in the food and beverage processing, pharmaceutical, and cosmetic industries (Wisnujati and Siswati, 2021). Consequently, chili peppers are in high demand and are classified among the nine staple commodities of Indonesian society, with consumption levels tending to increase annually. The substantial market demand for chili availability aligns with population growth and the expansion of both food and non-food enterprises (Pratiwi, 2021). However, according to data from the Indonesian Central Bureau of Statistics (2023), bird's eye chili production over the last five years has experienced significant fluctuations, even declining by up to 8.09%.

The primary factor affecting the productivity of bird's eye chili plants is the infestation of plant pests (OPT), which include both insects and plant pathogens (Inaya et al., 2022). Among the numerous pathogens causing diseases in bird's eye chili plants, *Sclerotium rolfsii* is a fungus that causes stem rot, wilting, and even damping-off, which threatens productivity and leads to economic losses (Hutauruk, 2018). Stem rot caused by *S. rolfsii* softens the outer tissue of the plant's stem base, subsequently causing the leaves to turn yellow and wilt. Symptoms of necrosis and wilting on the leaves are followed by the appearance of white hyphal aggregates on the infected tissues, resulting in rot at the base of the stem (Hutauruk et al., 2016).

S. rolfsii is a soil-borne pathogenic fungus capable of infecting more than 500 plant species across approximately 100 families, predominantly in tropical and subtropical regions (Javaid et al., 2023). *S. rolfsii* possesses excellent adaptability to extreme environments and can persist in the soil for extended periods without undergoing a dormancy period. This fungus survives by forming sclerotia in the soil, manure, and diseased plant debris (Sumartini, 2012). The dissemination of this fungus can occur through irrigation water and seeds in fields continuously cultivated with its host plants. *S. rolfsii* causes several lethal plant diseases, including stem rot, wilting, and damping-off.

The fungus *S. rolfsii* on bird's eye chili plants can cause seeds to rot within the soil, cause germinating seeds to die before emerging above the soil surface, and even attack the soft basal tissue of young seedlings (Hutauruk, 2018). Under humid conditions, *S. rolfsii* forms a cotton-like white mycelium at the stem base and on the soil surface, causing the stem base to become water-soaked, shriveled, and eventually leading the seedlings to lodge and die. When the dead plant is uprooted, a cluster of sclerotia can be seen adhering to the roots. The losses caused by this fungus can reach 80%, and if environmental conditions favor fungal growth, losses can reach 100% (Hidayat et al., 2015). Chili seedlings affected by damping-off disease have only a 10% chance of survival (Majeed et al., 2018).

Control efforts against *S. rolfsii* have involved cultural practices, crop rotation, and the use of resistant varieties (Kator et al., 2015); physical or mechanical methods such as uprooting infected plant parts (Sumartini, 2012); and the most widely used approach, which is spraying synthetic fungicide-class pesticides (Selviani et al., 2021). However, the active ingredients in chemical pesticides are persistent and exert adverse impacts on the environment. The widespread use of chemicals as pesticides can also induce the emergence of pesticide-resistant strains, threatening control efficacy (Sinambela, 2024). Therefore, alternative control methods that are environmentally friendly and effective are required to manage stem rot disease in bird's eye chili caused by *S. rolfsii*.

According to Jiao et al. (2021), Plant Growth-Promoting Rhizobacteria (PGPR) are among the biocontrol agents widely proven effective and utilized in controlling various plant pathogens. The indirect mechanisms of PGPR in enhancing a plant's capacity to control pathogens include the production of proteases, chitinases, cyanide, or antibiotics (Zhou et al., 2016). PGPR in the plant root zone can be categorized based on their colonization sites: those residing in the rhizosphere complex, those on the root surface (rhizoplane), and those inside the root tissue (endophytes) (Yanti et al., 2017).

Rhizobacteria are bacteria located in the soil surrounding the plant root zone that utilize root exudates as a nutrient source to produce various secondary metabolites beneficial for plant growth and development (Kristianti et al., 2023).

Rhizobacteria can play a role in inhibiting pathogen growth while simultaneously strengthening plant defenses through complex interactions (Amaria et al., 2019). Bacterial groups commonly found and deployed as biological agents include *Pseudomonas* (*P. putida* and *P. fluorescens*), *Streptomyces* spp., and *Bacillus* spp. (Mishra and Arora, 2018).

Streptomyces sp. is a Gram-positive bacterium belonging to the Actinomycetes group, capable of growing in various environmental settings, and microscopically characterized by a fungus-like filamentous structure (Procópio et al., 2012). This bacterium resides in the soil and plays a vital role in producing approximately 75% of commercial antibiotics (Miyadoh and Otaguro, 2004). *Streptomyces* possesses the capability to synthesize a diverse range of active compounds as secondary metabolites, such as hydrolases (glucanases and chitinases), herbicides, and substantial quantities of antibiotics (Thepbandit and Athinuwat, 2024). *Streptomyces* bacteria can suppress the growth of pathogenic fungi through control mechanisms involving antibiosis, hyperparasitism, and overgrowth (Sahriyanor et al., 2024).

The *Streptomyces* sp. isolate to be utilized in this study was isolated from the rhizosphere of the mangrove plant *Avicennia marina* located at the Surabaya Mangrove Botanical Garden. Mangroves are known as transitional ecosystems or ecotone zones, which are areas where terrestrial and marine ecosystems meet. Cultivating mangrove plants like *A. marina* aims to prevent seawater intrusion, counter coastal erosion and abrasion, as well as provide habitats and food sources for several wildlife species (Rinjani et al., 2022). Environmental conditions in mangroves for plant growth and microbial habitats are classified as extreme because they tend to have high and fluctuating salinity, are waterlogged and oxygen-depleted, possess very low pH values, and in some areas, exhibit exposure to toxic compounds due to ongoing decomposition and biogeochemical activities (Asrianti, 2023). Given these conditions, the *Streptomyces* sp. to be used as a biological agent naturally possesses a very high adaptability to various environmental conditions.

Research regarding the antagonistic properties of *Streptomyces* sp. has been conducted by Ersyaf (2025), utilizing various concentrations of secondary metabolites to control the growth rate of *S. rolfsii* both *in vitro* and *in vivo* on peanut

plants (*Arachis hypogaea* L.). The results demonstrated that, *in vitro*, a 25% concentration of secondary metabolites exhibited the highest inhibition rate at 33.8%, whereas, *in vivo*, *Streptomyces* sp. was deemed not yet optimal in suppressing *S. rolfsii* growth because the severity of stem rot disease remained above 70%. Nevertheless, numerous studies on the same topic have been widely conducted and have shown quite significant results.

Testing of the antagonistic properties of *Streptomyces* sp. against *S. rolfsii* has been widely performed *in vitro*, yielding results that indicate this bacterium is capable of suppressing *S. rolfsii* growth. Muthahanas and Listiana (2017) tested several *Streptomyces* spp. isolates *in vitro*, and the results showed that a *Streptomyces* sp. isolate originating from the shallot rhizosphere in Sembalun District, Lombok City, was able to inhibit the growth of the fungus *S. rolfsii* by up to 70%. Testing of the antagonistic traits of *Streptomyces* sp. was also conducted by Qiu et al. (2024) on chili plants, showing a control efficiency against *S. rolfsii* reaching 70.42%. Furthermore, the application of *Streptomyces* sp. also promoted substantial vegetative growth and increased chlorophyll production in chili plants. *Streptomyces* sp. can even inhibit the mycelial growth of the fungus *S. rolfsii* in *in vitro* assays by up to 98.7% (Abo-Zaid et al., 2021).

Seed treatment of chili seeds by soaking them in *Streptomyces* sp. for 10 and 20 minutes resulted in the lowest incidence of disease caused by *S. rolfsii*, at 8% (Wahyuni et al., 2017). Beyond seed treatments, protection via seedlings is also considered a fairly effective approach to reducing disease incidence and intensity (Edisaputra, 2005 in Rahayu et al., 2021). Research on controlling *S. rolfsii* by root-dipping chili seedlings in *Streptomyces* sp. remains scarce. However, seedling treatments are widely practiced, as seen in research by Marsuni (2020), where soaking the roots of chili seedlings in a suspension containing biological agents for 30 minutes, followed by draining for 30 minutes and re-soaking for 30 minutes, successfully suppressed the intensity of anthracnose disease severity. Seedling treatment was also performed by Jamarun and Yunisman (2017) by dipping the roots of chili seedlings into a conidial suspension of an antagonistic fungus for 15 minutes; the results showed that the antagonistic fungus was able to colonize the roots and suppress the intensity of anthracnose attacks by up to 80%.

Previous studies indicate that the origin of the isolate, the inoculation method of the antagonistic bacteria, and the root-soaking duration of the seedlings significantly influence the potential of *Streptomyces* sp. to suppress the development of the fungus *S. rolfsii*. Therefore, the author aims to determine the potential of a *Streptomyces* sp. isolate obtained from the mangrove rhizosphere to suppress the development of the fungus *S. rolfsii*, and to identify the effective root-soaking duration for chili seedlings to inhibit the occurrence of stem rot disease. Additionally, this study investigates whether the obtained *Streptomyces* sp. isolate can exhibit PGPR traits and influence the growth of chili plants.

1.2. Problem Statement

The questions of conducting this research are as follows:

1. To determine the potential of *Streptomyces* sp. isolated from the mangrove rhizosphere in inhibiting the growth of *Sclerotium rolfsii*?
2. To determine the effect of different root dipping durations in a *Streptomyces* sp. suspension on the development of stem rot disease and its subsequent impact on the growth of bird's eye chili plants?

1.3. Research Objective

The objectives of conducting this research are as follows:

1. To determine the potential of *Streptomyces* sp. isolated from the mangrove rhizosphere in inhibiting the growth of *Sclerotium rolfsii*.
2. To determine the effect of different root dipping durations in a *Streptomyces* sp. suspension on the development of stem rot disease and its subsequent impact on the growth of bird's eye chili plants.

1.4. Research Significance

The benefits of this research are to provide scientific information regarding the potential of *Streptomyces* sp. isolated from the mangrove rhizosphere as a biocontrol agent against the pathogenic fungus *Sclerotium rolfsii*, the causal agent of stem rot disease in bird's eye chili plants, as well as its effect on promoting the growth of bird's eye chili (*Capsicum frutescens* L.) through the root dipping method.