I. INTRODUCTION

1.1. Background

The spread of cadmium heavy metal pollution has been identified in various regions of Indonesia, including major islands such as Sumatra, Sulawesi, Bali, Java, Kalimantan, and Papua (Sutrisno & Henny, 2015). The cause of cadmium heavy metal pollution in agriculture is the use of various types of pesticides and phosphate fertilizers. Pesticides and phosphate fertilizers containing cadmium range from 30-60 mg/kg. The excessive use of pesticides and phosphate fertilizers in an intensive and sustained manner has the potential to cause the accumulation of heavy metal cadmium in agricultural land (Schipper *et al*., 2011).

The cadmium content in pesticides and phosphate fertilizers poses a risk of accumulation in the soil, absorption by plants, and entry into the food chain. This makes it a critical issue in efforts to ensure food safety and environmental health (Setyorini *et al*., 2003). Intensive agricultural areas such as Pengalengan, Karawang, Cirebon, Brebes, Subang, Tegal, Majalengka, and Indramayu are known as centers for rice and vegetable cultivation. Continuous agricultural practices without land fallowing, coupled with excessive use of chemical fertilizers and pesticides, have triggered the accumulation of heavy metals such as cadmium (Cd) in these agricultural lands (Sutrisno & Henny, 2015).

Cadmium is a silver-white metal that is soft, shiny, insoluble in bases, and difficult to react with, and forms cadmium oxide when heated (Istarani & Pandebesie, 2014). Cadmium is a non-essential micronutrient for plants, meaning its benefits are unknown and it can be toxic. Symptoms of cadmium toxicity in plants include chlorosis and stunted growth (Prasad, 2008). Additionally, cadmium can disrupt plant growth by inhibiting nutrient absorption, hindering cell expansion, and interfering with photosynthesis. Cadmium (Cd) is classified as a hazardous heavy metal for humans due to its carcinogenic properties when accumulated in the body over an extended period. Considering the toxicity of cadmium in plants, cadmium standards have been established based on Alloway, (1995) and the Soil Research Institute (2009), the toxic concentration level of cadmium in soil is 3–8 mg/kg.

Efforts to remediate soil and agricultural land contaminated with heavy metals must be carried out so that they can be safely used again. In remediating soil contaminated with heavy metals, physical and chemical techniques can be used, including ion exchange, evaporation, precipitation, chemical reduction, and reverse osmosis (Yulianti, 2021). However, the application of these methods is costly and can have negative impacts on the environment. One method considered simple and straightforward is bioremediation. Bioremediation is a strategy or process of converting harmful pollutants into non-harmful pollutants through the use of microorganisms, plants, or biocatalysts (Waluyo, 2018).

Bacteria from the genus *Bacillus* are often used in the bioremediation process. *Bacillus* has a unique characteristic, namely its ability to form spores. *Bacillus* spores have high resistance to various environmental stresses such as extreme temperatures, drought, humidity, and radiation exposure. This resistance supports its role as an effective bioremediation agent, particularly in reducing heavy metal contamination such as cadmium (Cd). Through enzymatic activity, *Bacillus* sp. can perform biosorption, which is the process of absorbing cadmium (Cd) into bacterial cells, thereby reducing the toxicity of the metal in the environment (Aznur *et al*., 2022). The *Bacillus* used in this study is a local *Bacillus* strain collected by Dr. Dra. Endang Tri Wahyu Prasetyawati, M. Si, which has been tested for resistance to cadmium (Cd). This aligns with the research by Purkan *et al*., (2017), which found that local *Bacillus* sp. bacteria show potential as mercury (Hg) bioremediation agents. The research by Maulana *et al*. (2017) also states that the *Bacillus* bacterial genus can serve as an effective bioremediation agent for heavy metals.

The FOBIO biopesticide formula is an organic pesticide based on microorganisms that functions as a biological agent, decomposer, and Plant Growth Promoting Rhizobacteria (PGPR). In addition to its role in biological control, FOBIO also contains nutrients that can enhance crop productivity. Its use supports sustainable agricultural systems while considering ecological aspects, environmental conservation, human health, and grassroots economics (Hasyidan, 2021). The microorganisms contained in the FOBIO biopesticide formula are expected to have the potential to reduce the accumulation of excessive heavy metals in the soil. According to research by Widya *et al*., (2022), the FOBIO biopesticide

formula can reduce the concentration of heavy metal Pb in the soil with an application of 0.59 ml / 0.05 liters per polybag weekly.

Green mustard plants (*Brassica rapa* L var. parachinensis) are plants that can absorb heavy metals from the soil or are resistant to heavy metal stress. The roots of mustard plants can extract various heavy metals from the soil and translocate them to other parts of the plant, such as the stem, leaves, and fruit. This process allows for the accumulation of heavy metals in certain plant parts (Panjaitan & Lamria, 2018). Therefore, in this study, mustard plants were used as an indicator to observe plant growth and symptoms of cadmium (Cd) heavy metal toxicity. Therefore, the objective of this study is to determine the potential of *Bacillus* sp., FOBIO biopesticide, and the growth of green mustard plants in soil contaminated with heavy metal cadmium (Cd).

1.2. Problem Formulation

Based on the background, the following problem formulation can be developed:

1. Can the heavy metal cadmium (Cd) content in soil be reduced after treatment with *Bacillus* sp. and FOBIO biopesticide?
2. Does the growth of green mustard plants (*Brassica rapa* L var. parachinensis) get messed up by cadmium (Cd) levels in the soil that are higher than normal?

1.3. Research Objectives

The objectives of this study are to:

1. Determine the cadmium (Cd) content before and after treatment with *Bacillus* sp. and FOBIO biopesticide.
2. Determine the growth of green mustard plants (*Brassica rapa* L var. panachinensis) in media contaminated with cadmium (Cd) exceeding normal limits.

1.4. Research Benefits

The benefits of this study are expected to contribute to the development of sustainable agricultural technology regarding the potential of *Bacillus* sp. bacteria and FOBIO biopesticide as bioremediation agents for heavy metal cadmium (Cd) and the growth of plants contaminated with heavy metal cadmium (Cd).