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The Impact of Biopesticide Application on Arthropod Composition in Surjan Cropping System in Kulonprogo Regency, Special Region of Yogyakarta

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Abstract. *Surjan is a specific type of cropping system that is part of a local wisdom practice found in Kulonprogo Regency, Special Region of Yogyakarta. The cropping system employs a polyculture system with a raised-sunken bed configuration. In ancient times, this system was initiated as a conservation initiative in the event of drought. In the context of agroecosystems, defined as the interaction between biotic and abiotic components, arthropods serve as indicators of the biotic components of the agricultural environment. The presence of arthropods is influenced by the use of synthetic pesticides. In response to the use of synthetic pesticides, biopesticides are frequently used as a countermeasure. The present study aims to ascertain the impact of biopesticide applications on the composition of arthropods in agricultural land that utilizes surjan cropping system configuration. This study was conducted on the surjan cropping system in Kulonprogo Regency, which is predominantly characterized by the cultivation of rice and shallots. The biopesticide used in this study was a group of fungi, namely Trichoderma harzianum and Metarhizium anisopliae. These organisms function as bioprotectants and biofertilizers. The findings indicate that surjan cropping system, when accompanied by biopesticide utilization, yield a greater diversity of arthropod species in comparison to surjan cropping system that employs synthetic pesticides. In agricultural land with surjan system configuration and biopesticide applications, certain arthropods function as predators, parasitoids, and bioindicators. The most prevalent arthropod species identified is Verania* sp. *(Coleoptera; Coccinelidae), with a total of 68 individuals. The present study has yielded findings indicating a correlation between the application of surjan cropping system and the utilization of biopesticides in land cultivated with a specificcrops and the composition of arthropods in the environment.*
Keywords: *arthropods; crops; fungi; surjan system; sustainable.*

Type of the Paper: Regular Article.

1. Introduction

Surjan is a specific type of cropping system that is part of a local wisdom practice found in Kulonprogo Regency, Special Region of Yogyakarta. It involves polyculture of horticulture and food crops. The distinguishing characteristic of this cropping system is the configuration of the

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soil media, which are designed to vary in elevation to accommodate different crops. In ancient times, this agricultural practice was employed to address irrigation problems during the dry season. In the contemporary era, its implementation is part of agroecosystem modification for the purpose of achieving sustainable land infrastructure [1]. The optimization of land resources is one part of conservation measures intended to counteract the occurrence of pests and diseases. Despite the implementation of surjan cropping system, farmers continue to rely on synthetic pesticides and fertilizers to protect their crops from pests and to increase plant growth.

Agroecosystem modification is part of the implementation of sustainable agriculture [2]. A healthy agroecosystem is characterized by an abundance of arthropods. Arthropods are one of the indicators of environmental health when exposed to synthetic materials [3]. The abundance of arthropods in an ecosystem is an indication that the ecosystem is relatively uncontaminated. Apart from arthropod pests, there are also arthropod natural enemies: predators and parasitoids. Furthermore, arthropods play a vital role in ecosystems as pollinators, biodecomposers, and bioindicators [4–6]. The existence of arthropods is very important for the maintenance of ecosystem sustainability and the conservation of land resources, as well as the well-being of plants. The implementation of surjan cropping system, for example, involves the cultivation of insectary plants (*refugia*) along the boundaries between fields, serving as hosts for natural enemies and as an integrated pest management [7].

Currently, farmers continue to rely on synthetic pesticides for the management of pests and diseases. The utilization of synthetic pesticides has been demonstrated to exert harmful effects, including the killing of non-targets. This has the potential to jeopardize the diversity of natural enemies and predators, thereby exacerbating pest populations [8]. Pests may exhibit a heightened degree of resistance to pesticides over time, and attack rates may concomitantly rise [9,10]. A secondary impact is the deterioration of land quality, which can manifest in the form of degradation and a decline in soil fertility levels [11].

An alternative to synthetic pesticides is the utilization of beneficial microbes, such as *Metarhizium anisopliae* and *Trichoderma harzianum*. These two microbes are biological agents from the fungi group and have potential applications in pest and disease control [12,13]. Both fungi have mechanisms of action and entry that ensure their exclusive targeting of their intended hosts. The resulting secondary metabolites of these fungi play an important role as protectants and biostimulants [14], and the hormones produced can trigger plant growth. It is anticipated that, following a prolonged period of application, these fungi will proliferate in nature, thereby ensuring ample availability [15,16].

The extant literature on surjan cropping system is scant, with few studies having been conducted to date. The most recent study investigated the arthropod populations in polyculture using surjan cropping system and in monoculture, revealing variations in arthropod abundance. The implementation of surjan cropping system has been demonstrated to result in a notable increase in the diversity and abundance of arthropod populations [17]. A study was conducted to compare the effects of conventional and surjan cropping systems on arthropod abundance. The results showed that surjan cropping system resulted in a higher abundance of arthropods compared to the conventional cropping system [18]. The application of conventional systems has led to the proliferation of pests such as *Bactrocera* sp. and *Arigona* sp. The utilization of surjan cropping system has been demonstrated to result in an increase in the abundance and diversity of arthropod natural enemies. In light of the aforementioned elaboration, the present study aims to ascertain the influence of the application of biopesticides derived from fungal active ingredients (*M. anisopliae* and *T. harzianum*) on arthropod diversity within agricultural environments configured using surjan cropping system.

2. Materials and Methods

2.1. Study area

The study was conducted in an agricultural area with surjan cropping system configuration, located in Panjatan District, Kulonprogo Regency, Special Region of Yogyakarta. The area is located at coordinates -7.916343,110.1108008; -7.9063609,110.1711428 (Fig. 1). The study was conducted from April to November 2023, coinciding with the rice and shallot planting season. All farmers applied a simultaneous and uniform planting pattern. The treatments were administered to rice crops at 52 days after planting (DAP) and to shallot crops at 21 DAP. The cultivation was performed in accordance with the conventional practices of the farmers. However, in order to facilitate the administration of biopesticide treatment, the farmers were prohibited from using synthetic pesticides.

2.2. Rejuvenation and formulation of biopesticides

A suspension of 0.1 mL of pure isolate was obtained using a syringe needle and placed in a Petri dish containing PDA (*potatoes dextrose agar*) media in a sterile environment. The suspension in the Petri dish containing PDA media was flattened by rotating it. Subsequently, the Petri dish was closed and wrapped in order to prevent contamination from external sources. Next, pure isolates of *M. anisopliae* and *T. harzianum* were propagated in test tubes with PDA media as a starter for propagation with 100 g of corn media. Following inoculation, the cultures were subjected to incubation at room temperature for a period of 7−10 days, until the fungi had proliferated to the point of covering the surface of the corn media (Fig. 2). The corn media that had been covered with fungi was then ground using a flour machine, producing *mycogranules* that were ready to be applied. The concentration of spores used in the demonstration plot was 10^8 spore

L^{-1}.

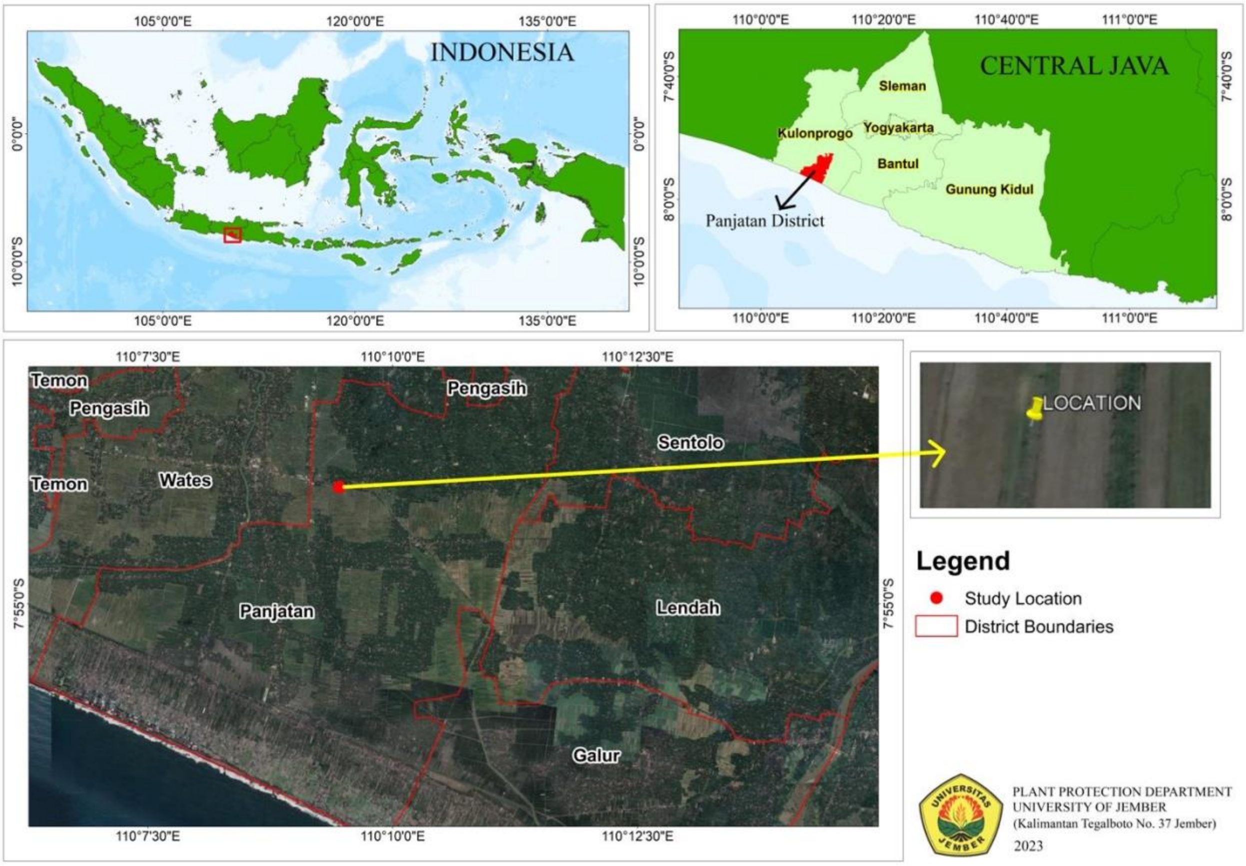

Fig. 1. Research location

2.3. Observations and applications

Observations were conducted at several diagonal points of the sample and on two demonstration plots: one receiving biopesticide application and another receiving synthetic pesticide. The biopesticide was administered to rice crops at 52 DAP and to shallot crops at 21 DAP. The concentration of entomopathogenic fungi was determined to be 10^8 spores mL^{-1}. The biopesticide was administered in a three-times-per-week manner. Concurrently, observations were conducted over a three-day interval until the conclusion of the vegetative phase.

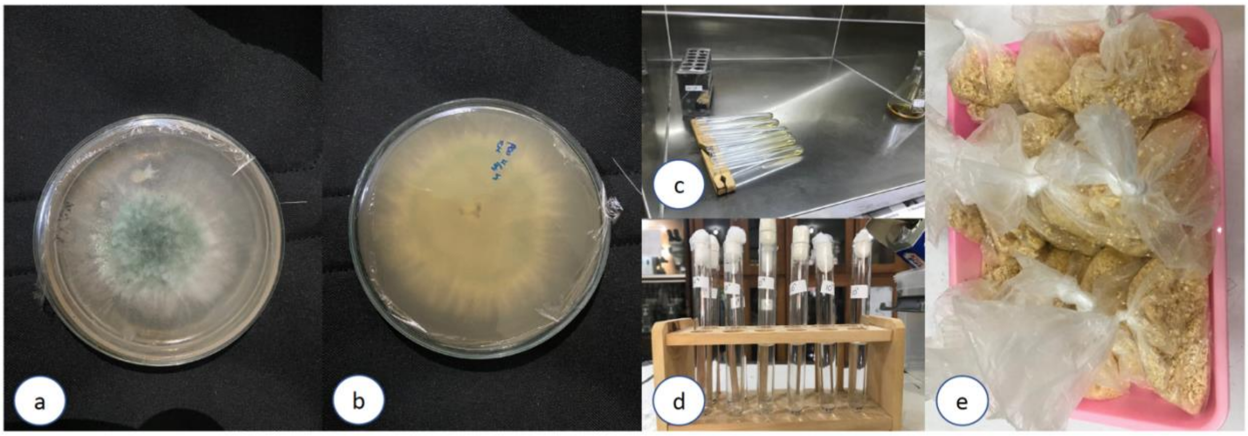

Fig. 2. Biopesticide rejuvenation and formulation: a) *T. harzianum* isolate; b) *M. anisoplae* isolate; c) propagation in slant tubes; d) dilution process; and e) solid media formulation

2.4. Experimental design and data analysis

The experimental design was implemented by allocating land for biopesticide application and land cultivated through conventional farming practices (Fig. 3). The land size was 250 m^2 for each rice crop and shallot crop. The land area was 150 m^2 for the purpose of control. The designated treatment land is located in proximity to a technical irrigation area, where the quantity of water can be controlled. The samples observed included a population of arthropods, comprising pests and natural enemies. To complement the observational data, sweep netting was conducted on ten separate occasions. The collected arthropods were preserved in a vial containing a solution of formalin (25 mL), acetic acid (1 mL), water (15 mL), and distilled water [19,20]. The samples were then examined under a stereo microscope (Leica) to facilitate identification. The analysis was conducted using both descriptive and quantitative methods. The instrument used for the measurement of diversity indicators was PAST 4.11 software.

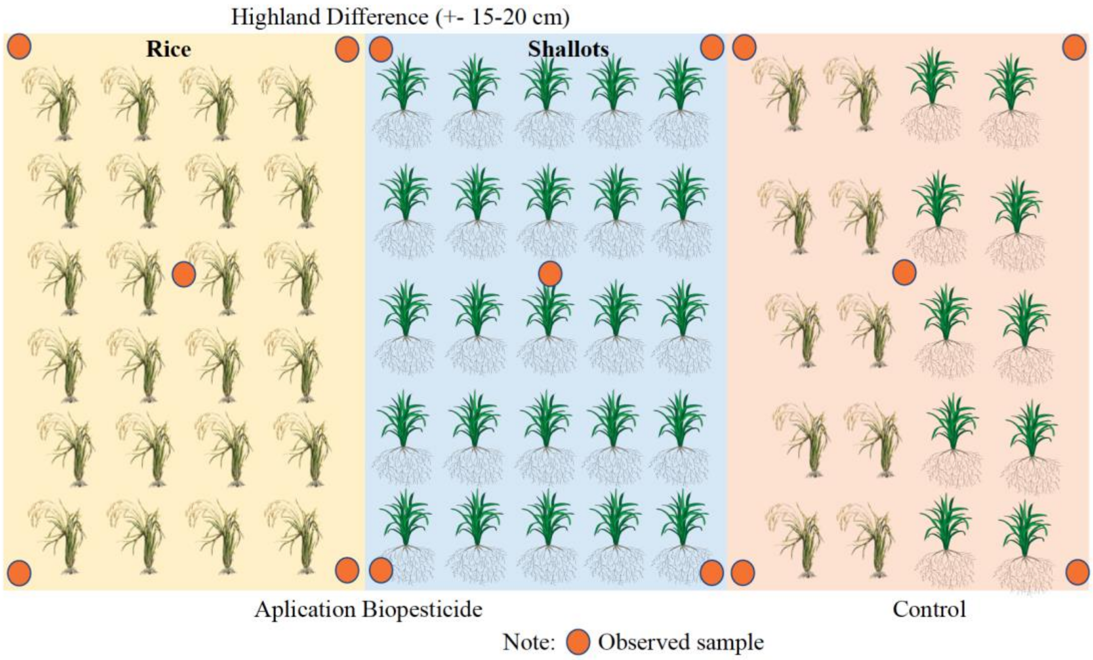

Fig. 3. Illustration of the experimental design for the application of biopesticide and the control treatment

3. Results and Discussion

Sustainable agriculture can be defined as a cultivation system that prioritize environmental sustainability. Surjan cropping system is one of the habitat modifications employed for integrated pest management. Habitat modification is an integrated part of the agroecosystem, serving to disrupt the cycle of pest development. The modification of habitat within surjan cropping system configuration involves the combination of polyculture with different bed elevation configurations for different crops. Prior to planting, farmers usually till the soil to break the life cycle of pests. Additionally, it was observed that in their agricultural practices, farmers use insectary plants (*refugia*), which serve as hosts for natural enemies. The insectary plants utilized include sunflowers, cosmos, zinnias, and rose balsams [21,22]. Conversely, the conventional system mirrors the monoculture system and relies heavily on the utilization of synthetic pesticides.

Arthropods are the dominant biotic components in the rice field ecosystem and are described as indicators of environmental health. The presence of arthropods is greatly influenced by the actions and practices of farmers. The more intensively synthetic pesticides are used, the greater the likelihood of a decline in arthropod populations due to the fact that these chemicals, designed to target a broad range of organisms, can also affect non-target species. Arthropods have functions that involve interactions with exosystems. For example, they serve as predatory enemies, natural enemies, bioindicators, pollinators, and decomposers. In sum, arthropods act as a medium for plant interaction with the environment. However, there are species of arthropods that are pests, posing a threat to farmers and leading to crop failure if left unchecked. The implementation of environmentally friendly agricultural practices is recommended, and this can be achieved by exercising caution and restraint in the application of synthetic pesticides. An alternative recommendation could be the utilization of biological agents, such as *M. anisopliae* and *T. harzianum*. In the context of surjan cropping system configuration in Kulonprogo, farmers have implemented a complex agroecosystem involving habitat manipulation. Nevertheless, synthetic pesticides are still used intensively.

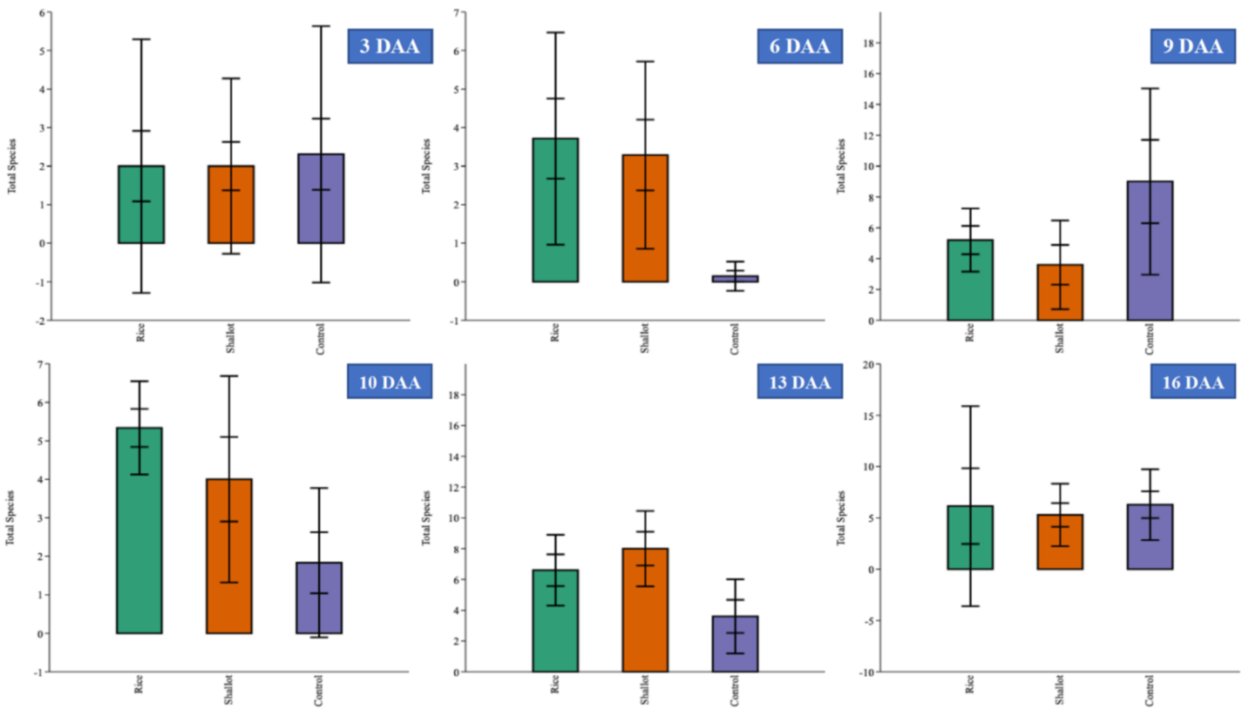

Fig. 4. Abundance of arthropods due to biopesticide application

The present study was conducted for the purpose of investigating the composition of arthropod population in relation to biopesticide application. To date, the utilization of biopesticides containing active fungal ingredients for the management of pests and diseases has not been previously documented. *Metarhizium anisopliae*, an entomopathogenic fungus, has been utilized to control various pests. This fungus produces secondary metabolites, including tropolone, citrinin, phenomonic acid, and azaphilone [23]. *Metarhizium anisopliae* has demonstrated effectiveness in the management of pests across various orders [13,24]. *Trichoderma harzianum* is a fungus that produces indole-3-acetic acid (IAA), a hormone that stimulates plant growth [25]. The mechanism by which this occurs involves an increase in the activities of certain enzymes, including SOD, POD and APX. Indole-3-acetic acid (IAA) is a biostimulant that is produced by plant growth-promoting microbes (PGPM), including Sphingomonas and Gemmatimonas, in addition to Trichoderma [26].

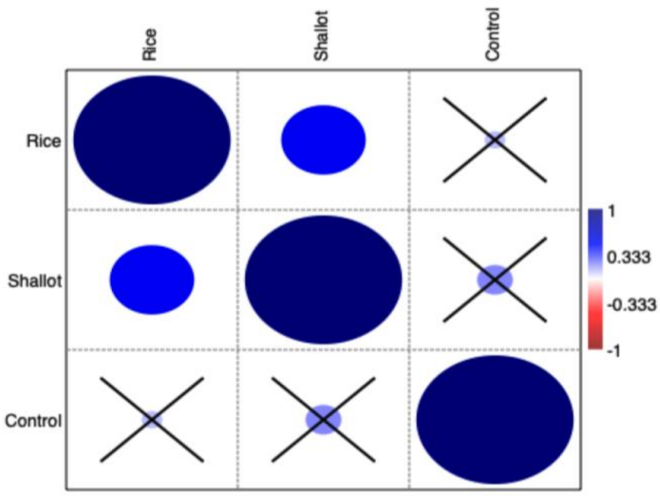

Fig. 5. Correlation between the types of crops cultivated and biopesticide applications

Fig. 4 presents the results of the analysis of arthropod composition in each observation period. The presence of arthropods was observed at three-day intervals following the application of the biopesticide and the farmer's conventional farming method (control). The box plots illustrating the entire composition of arthropods collected are displayed in Fig. 5. The composition of the box plots presented is dynamic and varied. The observed crops were rice and shallots, with a combination of both in the control treatment. The highest diversity of arthropods was found in the agricultural area planted with rice crops. At the time of observation, the rice had reached 52 DAP, marking the onset of the vegetative phase. The observation was conducted by collecting all the arthropods present. In the agricultural area that received the control treatment, the composition of arthropods exhibited a tendency to be less than the total species found. This result was attributed to the application of synthetic pesticides as the control treatment within the study area. The efficacy of synthetic pesticides is typically more immediate than that of biopesticides. The efficacy of biopesticides, while less immediate, is characterized by their ability to target specific pests. As illustrated by the box plot, the arthropod composition in the agricultural area with surjan system configuration, coupled with biopesticide application, was more abundant than in the agricultural area with surjan system configuration and synthetic pesticide application (control).

Table 1. Inventarization and composition of arthropods in area with surjan system configuration and biopesticide application

Arthropods	Status	Order	Family	Total Number of Individuals	Reference Key Identification
Verania sp.	Predator	Coleoptera	Coccinelidae	68	[27]
Hololena sp.	Predator	Araneae	Agelenidae	46	[28]
Atherigona sp.	Pest	Diptera	Muscidae	7	[29]
Anisoptera sp.	Bioindicators	Odonata	Gomphidae	15	[30]
Scirpophaga sp.	Pest	Lepidoptera	Crambidae	28	[31]
Haltica sp.	Herbivore	Coleoptera	Halticidae	13	[32]
Menochilus sp.	Predator	Coleoptera	Coccinellidae	11	[33]
Scymnus sp.	Predator	Coleoptera	Coccinellidae	52	[34]
Leptocorisa accuta	Pest	Hemiptera	Alydidae	38	[35]
Nilaparvata lugens	Pest	Hempitera	Delphacidae	28	[36]
Oxya sp.	Pest	Orthoptera	Acrididae	13	[37]
Brachonidae	Parasitoid	Hymenoptera	Braconidae	8	[38]
Formicidae	Predator	Hymenoptera	Formicidae	32	[39]

The findings of this study demonstrated a correlation between the response of arthropod composition and differences in biopesticide treatment and farmers' conventional methods, both of which incorporated surjan cropping system. As illustrated in Fig. 5, there was no correlation between the two crops (i.e., rice and shallots) and biopesticide application. However, a significant difference in arthropod composition was observed in the agricultural area with surjan cropping system configuration and biopesticide treatment. This phenomenon can be posited as a recommendation for integrated pest management. The symbol (x) in the analysis results signifies the absence of a discernible correlation or the presence of an extremely negligible correlation. In contrast, the large oval symbol indicates a high degree of correlation.

Table 2. Inventarization and composition of arthropods in area with surjan system configuration (control)

Arthropods	Status	Order	Family	Total Number of Individuals	Reference Key Identification
Verania sp.	Predator	Coleoptera	Coccinelidae	30	[27]
Hololena sp.	Predator	Araneae	Agelenidae	21	[28]
Atherigona sp.	Pest	Diptera	Muscidae	15	[29]
Anisoptera sp.	Bioindicators	Odonata	Gomphidae	2	[30]
Scirpophaga sp.	Pest	Lepidoptera	Crambidae	58	[31]
Leptocorisa accuta	Pest	Hempitera	Alydidae	35	[35]
Paederus fuscipes	Predator	Coleoptera	Coccinellidae	2	[40]
Spodoptera exigua	Pest	Lepidoptera	Noctuidae	23	[41]

As illustrated in Table 1, the composition of arthropods in the area with surjan system configuration and biopesticide applications exhibited a greater number of species. In Table 1, the arthropods have been classified based on their status and function in the agroecosystem components. In the area where biopesticides were applied, predators such as *Verania* sp. became the most dominant natural enemy. The number of predators and bioindicators was found to be higher in areas that had undergone biopesticide treatment in comparison to area that had received the control treatment. This finding suggests that the biopesticide is effective in targeting specific pests without causing harm to natural enemies, as indicated by previous studies [42,43]. Conversely, as illustrated in Table 2, the number of arthropod species identified following farmers' application of synthetic pesticides as a control treatment was diminished. The utilization of synthetic pesticides can exterminate pests while concurrently eliminating natural enemies within an ecosystem. Prolonged utilization can lead to the development of resistance, resulting in a more prevalent and aggressive pest population.

4. Conclusions

The application of biopesticide within surjan cropping system configuration does not result in the disruption of natural enemy populations. In the agricultural area characterized by surjan cropping system configuration, the composition of arthropod species exhibited greater diversity following biopesticide application in comparison to synthetic pesticide application. In the area with surjan system configuration and biopesticide application, the composition of predatory arthropods was dominated by *Verania* sp., with a total abundance of 68 individuals, followed by *Scymnus* sp. with 52 individuals and *Hololena* sp. with 46 individuals. The dominant species within the order Coleoptera and the family Coccinelidae were identified. In the agricultural area with surjan system configuration and synthetic pesticide application (control), the number of arthropod species was found to be reduced, while the pest population exhibited greater dominance in comparison to natural enemies.

Abbreviations

Not applicable.

Data Availability Statement

Data will be made available upon request.

CRediT Authorship Contribution Statement

Wagiyana: Conceptualization, Data curation. **Suharto**: Formal analysis. **Bakhroini Habriantono**: Funding acquisition. **Suhartiningsih Dwi Nurcahyanti**: Investigation, Methodology. **Mohammad Nur Khozin**: Project administration. **Dimas Ganda Permana Putra**: Resources. **Farchan Mushaf Al Ramadhani**: Software operation, Supervision. **Rachmi Masnilah**: Validation. **Gusna Merina**: Visualization. **Fariz Kustiawan Alfarisy**: Conceptualization, Data Curation, Writing – original draft, Writing – review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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