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Full Length Article

The Important Role of Ants in Protecting Soybeans (*Glycine max*): A Case Study in Maros District, South Sulawesi, Indonesia

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Abstract

Ants are social predatory insects found on a variety of crops in many parts of the world, including Indonesia. A study was carried out in 2022 at soybean fields in Sambueja Village, Maros Regency, South Sulawesi, to evaluate ant diversity in soybean plants and their effectiveness as pest control. The research was conducted on an area of 1,575 m^2 with several stages, namely identifying the main ant nests in the soybean planting area, mapping ant trajectories in the field, testing the potential and role of ants in controlling the larvae and pupae of the main pests of soybean crops, and testing the response of ants to artificial feed using anchovy waste. The results showed that four ant species were found, namely *Solenopsis invicta*, *Odontoponera denticulata*, *Tapinoma melanocephalum* and *Anoplolepis gracilipes*. There are two species that act as pest predators, namely *S. invicta* and *A. gracilipes*. It was concluded that *S. invicta* has the highest distribution of prey on pests. This makes it a potential candidate for the biological control of soybean pests. One way to maintain ant populations in soybean fields is through artificial feeding.

Keywords: Ant species; Food crops; Pest predator; *Solenopsis invicta*; Soybean

Introduction

Soybean (*Glycine max* L.) is one of the important food commodities prioritized for increased production (Gaonkar and Rosentrater 2019). In Indonesia, soybean is still the main food source, but its production has decreased every year, resulting in dependence on imports (Widowati and Handayani 2023). According to the FUSDA (2022), Indonesia imported 85% (2.65 million metric tons) of the 3.075 million metric tons of soybeans needed in 2021. Soybeans are also produced locally in South Sulawesi. However, there has been a significant decline in production over the past five years (Wahyuningsih 2022). The decline in soybean production can be caused by various factors, one of which is pest attacks. Pests are a significant obstacle to increasing soybean production (Fattah *et al.* 2022). More than 100 types of pests can attack and reduce soybean production, and some of them have the status of major pests, such as *Riptortus linearis*, *Nezara viridula*, *Ophiomyia phaseoli*, *Etiella zinckenella* and *Spodoptera litura* (Mulyaningsih 2017; Ginting *et al.* 2022). Soybean pests can cause damage from germination to harvest, even during storage. Although natural predators exist in the soybean ecosystem, their effectiveness against destructive pests is not fully known.

Predators are generally polyphagous and widely found in the field and soybean ecosystems. Ants are one of the predators that are commonly found and are the focus of this study because ants are one of the main predators that protect plants from pests. These predatory ants can be found in agroecosystems and native ecosystems. For example, *Solenopsis geminata* is a colonial predator that preys on many pests (Wetterer *et al.* 2006). This species is a very active and aggressive ant in search of prey (Abdullah *et al.* 2023). Ants were considered appropriate biological control agents in this study due to their high abundance on the soil surface in some annual crops, and they ranked first among predatory arthropods (Abdullah *et al.* 2020a). Their

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populations remain stable throughout the seasons and years, making them an important insect colony in ecosystems due to their abundance, significant functions, and complex interactions with their respective ecosystems.

Several studies (Haneda and Yuniar 2020; Diyasti and Maryani 2022) have examined the role of ants in ecosystems. However, these studies did not specifically investigate ant diversity in food crops and their effectiveness as pest control agents. However, these studies did not specifically investigate ant diversity in food crops and their effectiveness as pest control agents. Haneda and Yuniar's (2020) study only focused on the role of ants in a changing lowland tropical rainforest ecosystem. This research is worth considering in aspects of biological control, such as the role of ants, where the use of biological control agents to control pests is the right choice to reduce the use of chemicals in the agricultural sector. Previous research has shown that predatory ants in Brazil can be used as a control agent for sugarcane stem borer larval density (Rossi and Flower 2002). In addition, the presence of black ants (*Dolichoderus* sp.) can reduce the population and infestation of leafminers (*Phyllocnistis citrella* Stain) on citrus plants (Depparaba and Mamesah 2005).

Functional relationships between pests and natural enemies will be effective if certain requirements are met. These requirements include the ability of the natural enemy to find the host or prey, the minimum number of natural enemy populations needed to control the host or prey, synchronization and phenology between the natural enemy and host or prey, and a consistent food supply for biological agents to survive.

Therefore, this study aims to determine the diversity of ants in soybean plants and their effectiveness as pest control. In addition, to bring new contributions to the field of soya pest control by highlighting the role of ant species in agricultural ecosystems, one novel aspect offered by this research is the holistic approach to considering the natural role of ant species as pest control agents for soybean crops. Although there have been several studies on soybean pest control, this research provides a more specific focus on the role of ant species in pest control, specifically in Maros District, South Sulawesi, Indonesia. The justification for this research is based on the urgency to develop more sustainable and effective pest control strategies that not only reduce dependence on chemical pesticides but also take into account environmental sustainability and farmers' welfare. By highlighting this new aspect, this research is expected to contribute to the development of a more sustainable and effective pest control strategy.

Materials and Methods

Study area and research period

The location and time of the research were conducted throughout 2022 in Sambueja Village, Simbang Sub-district, Maros District, South Sulawesi, at geographical coordinates 5°03'46.4 "N and 119°41'16.8 "East.

Details of the experiment

The experimental stages in this study consisted of four steps.
Identify the main ant nest: Identifying the ants was the first step in this study. The identification process was done carefully to ensure the accuracy and reliability of the data received. We did this by visiting areas known to have high ant populations in the soya planting areas. Together with the research team, we conducted surveys to look for signs of ant activity, such as ant trails and nests. After finding areas where ants were potentially active, we looked carefully to find the main nest. We used tools such as tweezers and brushes to examine and identify the ant nests we found. After locating potential nests, we made further observations and collected 15–30 samples of ant species in the study area. We recorded the physical characteristics of the ant nests, such as size, shape, and the materials used to build the nests. In addition, we also recorded the behavior of ants leaving and entering the nest to aid species identification. The data collected was then analyzed in more detail in the laboratory using reference literature on ant species, namely *Australian Ants Key* (Shattuck 2001), *A Field Key to The Ants* (Hymenoptera, Formicidae) (Plowes and Patrock 2000) and the book Inventory and Collection (Hashimoto and Rahman 2003). These ant nest identification steps provided a solid foundation to continue our research exploring the role of ant species in soybean pest control.
Trajectory mapping of ants: This was the second step, where we carried out a series of organized and systematic steps. Mapping involved dividing the study area into smaller sections and then conducting direct surveys in the field, using topographic maps as a guide to record the locations and routes of observed ant trails. After locating the ant trails, we noted and recorded various aspects, such as the length of the trails, the direction of movement, and the number of main and transit nests. During mapping, we used field equipment such as GPS mapping, cameras for visual documentation, and field notes to record all relevant observations. We also mapped ant trajectories at various times of the day to understand different ant movement patterns.
Testing of soybean pest larvae and pupae: This stage aims to determine the potential role of ants in pest control. Tests were conducted by searching for larvae and pupae in the main pests of soybean plants. Once obtained, tests were conducted on selected plants. The test plants were located at a distance of 1–2 m from the observed ants. Then, take the larvae or pupae and place them on the test plants. Each replicate used three larvae, or pupae, per test plant. Next, observe and record the time of first ant arrival on the tested larvae or pupae and the number of colonies that arrive.
Ant attraction test with artificial food: This stage is the final stage, which involves conducting an attraction test

using anchovy waste. The predation stage, which involves artificial food, aims to determine the speed at which the ants respond to the food provided. This was done using dried, mashed fish waste that was no longer fit for consumption. The waste was mashed to make it uniform in size and volume then weighed as much as 10 g for each replicate. Feed testing was carried out by placing the feed in a container 1 m away from the ants to be tested. The time of arrival of the ants and the number of colonies were observed. Testing was carried out for 1 h and the number of colonies arriving was recorded every 10 min. The anchovy waste feed test was replicated three times for one ant species on different days and the remaining feed was weighed (Fig. 1).

Data analysis

Data analysis was conducted using Microsoft Excel 2016 software to organize and visualize the data. Statistical analyses were conducted using the ANOVA (Analysis of Variance) method to compare significant differences between different treatments and identify significant influences of the variables under study on the observed responses. This analysis procedure was used to support the research findings and draw stronger conclusions based on the empirical data collected.

Results

Identification of ants

Four ant species with different characteristics were identified through field observations and laboratory analyses, namely: *Anoplolepis gracilipes, S. invicta, Tapinoma melanocephalum* and *Odontoponera denticulata* (Fig. 2). *A. gracilipes* ants are characterized by a yellow body, long legs and claws, long antennae consisting of 11–12 segments, smooth books all over the body and a bright shiny body (Fig. 2a); *S. invicta* ants have a red body, relatively small eyes, jaws, and mandibles with teeth, spines on the propodium, and a small body (Fig. 2b); *T. melanocephalumi* is characterized by a dark brown head and thorax with colored gaster and opaque or milky white legs (Fig. 2c); and *O. denticulata* ants have a black body, one cone-like node, mandibles with teeth, antennae and books all over the body (Fig. 2d).

Distribution and abundance of ants

Based on observations made in the study area of 35 m x 45 m (1,575 m^2), ant nests and trails were found on soybean plants (Table 1). Ants are a type of insect with stable populations throughout the season and year, making them an important part of the ecosystem. They are known for their organized colonies and nests. The size of ant colonies occupying nests varies, ranging from tens to thousands of individuals. Table 1 shows that *S. invicta* had the most main and transit nests, with 6 main nests and 12 transit nests, with a path circumference of 115.5 m. *T. melanocephalum* had 1 main nest, 2 transit nests, and a path circumference of 22 m. *O. denticulata* has 1 main nest, 1 transit nest, and a path circumference of 20 m. *A. gracilipes* had 1 main nest, 1 transit nest, and a path circumference of 9 m. Overall, there were 9 main nests, 16 transit nests and a path circumference of 162.5 m.

Effect of ant presence on larval and pupal predation

The role of ants in the presence of pests was studied using larval and pupal tests of the soya leafminer, *Lamprosema indicata* Fabricius. The results showed ant responses in terms of initial arrival time, population size and predation (Fig. 3).

Fig. 3 displays the initial arrival time of ants in the larval and pupal tests. Specifically, *S. invicta* species arrived at 99.66 ± 78.23 min in the larval test and 44.11 ± 24.55 min in the pupal test. The species *A. gracilipes* arrived at 76.40 ± 28.33 min in the larval test and at 0 min in the pupal test. No ants were found for *O. denticulata* and *T. melanocephalum* species. The presence of *L. indicata* Fabricius pupae and larvae attracted *S. invicta* species with larger populations than *A. gracilipes, O. denticulata,* and *T. melanocephalum*. In the larval test, *S. invicta* had an average of 65.33 ± 43.01 ants, while *A. gracilipes* had an average of 9.67 ± 8.33 larvae and 0.33 ± 0.57 pupae. No ants were found on *O. denticulata* and *T. melanocephalum*. These Figures indicate that *S. invicta* preyed on the most larvae and pupae, with an average of 2.33 ± 0.57 larvae and 0.33 ± 0.57 pupae. *A. gracilipes* followed with an average of 2 ± 1.73 larvae and 0.33 ± 0.57 pupae, while *O. denticulata* and *T. melanocephalum* did not prey on larvae or pupae.

Response of ants to artificial food test

Crushed anchovies were used as artificial food to compare the ants' field foraging speed, colony carrying ability, and preying ability (Fig. 4). Fig. 4 displays the ants' arrival times for the test food, which was positioned 1 m from the anthill and consisted of 10 g of food. *T. melanocephalum* showed the fastest arrival time, with an average of 41.67 sec, followed by *O. denticulata* with 47.33 sec and *A. gracilipes* with 55 sec. The slowest arrival time was observed for *S. invicta*, with an average of 64.33 sec. However, observations of population abundance showed that *S. invicta* had the highest average number of ants arriving every 10 min for the dried fish (anchovy) food test, with an average of 154 ants. *T. melanocephalum* followed with an average of 85. The average arrival of *O. denticulata* species was 38, while that of *A. gracilipes* was 12. During one h of observation, *S. invicta* showed the highest consumption of anchovy waste feed, with an average of 1.09 g. *T. melanocephalum* consumed an average of 1.05 g, followed by *A. gracilipes* with 0.51 g. *O. denticulata* had the lowest average consumption of 0.40 g.

Table 1: Distribution and abundance of ants in soybean crop areas

Ant species	Primary nest	Transit nest	Trajectory circumference (m)
Solenopsis invicta	6	12	111,5
Odontoponera denticulata	1	1	20
Tapinoma melanocephalum	1	2	22
Anoplolepis gracilipes	1	1	9
Total	9	16	162,5

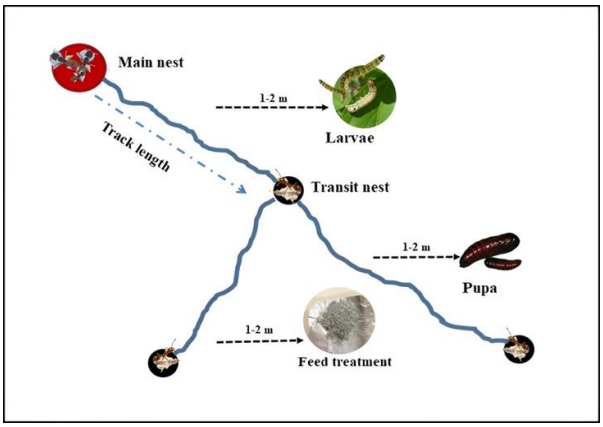

Fig. 1: Test method for ant attraction to artificial food at soybean field research site

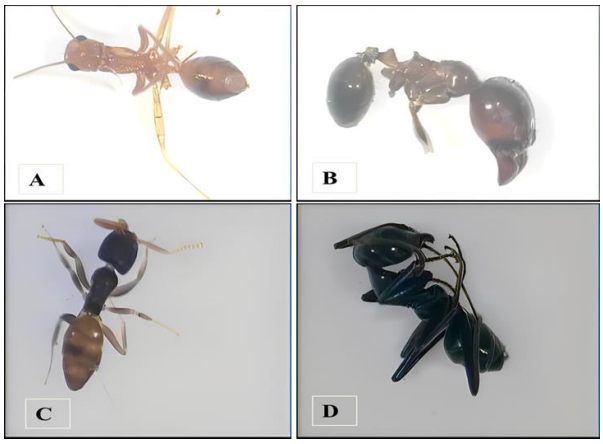

Fig. 2: Ant species found in soybean crops: (**A**) *A. gracilipes,* (**B**) *S. invicta,* (C) *T. melanocephalum* and (**D**) *O. denticulate*

Discussion

In the ecosystem of soybean plantations, four types of ants with different characteristics and population numbers were found. Based on observations and identification in the field and laboratory, four (four) types of ants were found, namely: *S. invicta, O. denticulata, T. melanocephalum* and *Anololepis*. These four ants inhabit the same ecosystem on the soya plantation. *A. gracilipes* is characterized by a yellow body, long legs and claws, long antennae consisting of 11–12 segments, smooth books all over the body and a bright, shiny body. *A. gracilipes*, commonly called the long-legged ant (Wetterer 2005; Man and Lee 2012;

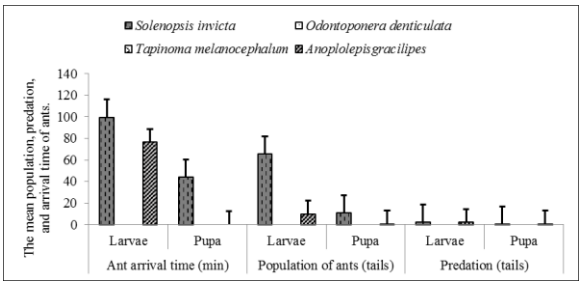

Fig. 3: Ant response in terms of initial arrival time, population size and predation on soybean leaf miner, *L. indicata* through larval and pupal tests

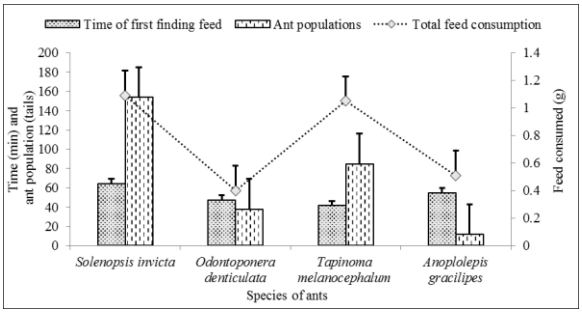

Fig. 4: Ant response to artificial feeding of the waste anchovies

Entomological Society of America 2021), is elongated (4–5 mm) and slender with a brownish yellow (sometimes brownish red) body and a darker abdomen. They do not have the ability to sting, but their stomach has pores that can secrete formic acid. Ants' legs and antennae are very long. The insect's antennae consist of 11 segments and are 1.5–2 times longer than its head. The clypeus is convex along the anterior edge. The mandible has eight teeth (Csurhes and Hankamer 2016; Lee and Yang 2022). *S. invicta* has a red body, relatively small eyes, jaws, and mandibles with teeth, spines on the propodium and a small body size. *S. invicta* is easily recognizable in the field due to its large nests, aggressive stinging behavior, and relatively small size (the total length of worker ants is 2.4–6.0 mm). It is usually black or red in color. Diagnostic features for the worker caste include the presence of 10 antennae on the antennae, with the apical two antennae forming a club. The propodeum lacks spines or other protrusions, the loin has two knots and the gaster has a prominent sting. Females are larger than workers, measuring 7.0–7.5 mm in overall length, and have 11 antennae. Male ants are slightly larger than female worker ants, measuring 5.0–6.0 mm in total length. Their bodies are entirely black, with a small head in proportion to the body and enlarged eyes. They have 12 antennae (MacGown *et al.* 2021; Seltzer *et al.* 2023).

T. melanocephalum ants are characterized by a dark brown head and thorax with colored gasters and opaque or milky white legs. *T. melanocephalum* is commonly called a 'ghost ant' and is a small (1.3–1.9 mm) ant species that is easy to identify. The head and chelicerae are brownish in

color, while the antennae, mandibles, limbs and abdomen are white or pale yellow (Klotz 2008; Pinto 2024). Meanwhile, *O. denticulata* ants have a black body, one cone-like node, mandibles with teeth, antennae, and books all over the body. *Odontoponera* is a small genus in the subfamily Ponerinae of the family Formicidae. It consists of only two extant species: *O. denticulata* and *O. transversa* (Bolton 1995; Bharti *et al.* 2013). *O. denticulata* is considered a distinct species due to its distinguishing features, such as having relatively shorter antennae that generally pass through the posterior edge of the head, less than the length of the first funicular segment. In addition, it has relatively larger eyes. There is a less obvious prominent area on the top of the head and the rugae on the mesosoma are in poor condition. The subpetiolar process has a long and dense pilosity. The propodeum has more than two larger teeth. The body color is much darker, with reddish legs (Hazarika and Khanikor 2021).

There are two types of ants: terrestrial and arboreal. Terrestrial ants nest and work on the ground, while arboreal ants spend their lives in trees (Drescher *et al.* 2011). According to the results of Nazarreta *et al.* (2021) research, there are several types of ants that belong to the arboreal ant species, one of which is the *Tapinoma* sp. species. During the research, very many individuals of this ant species were found on the trunks of several trees around the soybean planting area. *A. gracilipes*, *S. invicta*, and *O. denticulata* are ant species that have a high level of adaptation and are able to form large supercolonies. In addition, these species generally build nests on the soil surface or on litter found on the soil surface (Apriyadi *et al.* 2016; Ruslan 2019).

Ant species diversity in the field is influenced by the ecosystem; this is in accordance with the opinion of Agosti *et al.* (2000) that the presence of ants is closely related to habitat conditions, where low temperatures, unsuitable habitat for nesting, limited food sources and unfavorable home ranges are the main limiting factors. Observations on ant abundance and distribution showed that ants were present throughout the plantation through various pathways. Ants tend to collect food in the main nest and reproduce there, as evidenced by the presence of food and eggs. Ants are widespread in the field and can be found in almost all areas, especially the species *S. invicta*. These most populous ants are active at all times in search of prey. However, in hot weather, they tend to seek shelter under the plant's surface. *S. invicta* ants come in three types: queens, soldiers, and workers, each with different roles and tasks. Worker ants are responsible for transporting food. Hölldobler and Wilson (2009), Fewel (2015) and Abdullah *et al.* (2020b) support the idea that fire ants, *S. invicta*, are highly social insects that live in well-organized colonies. These colonies can consist of thousands of ants and are divided into worker ants, male ants, and queen ants. These ants can control and use large areas to support their activities.

Ants have various roles in the ecosystem. Observations in the field show that some ant species are effective in controlling pests on soybean plants, especially in the pupal and larval phases. *S. invicta* ants are widespread throughout soya plantations and are very active in the morning. It preys more on larvae than other phases due to its movement and soft body, making it easier to catch. Although *Odontoponera* ants did not prey on the larvae and pupae of the test pests, they were more active in feeding on weed seeds. Meanwhile, *A. gracilipes* ants were more aggressive in preying on larvae. Meanwhile, *T. melanocephalum* ants, also known as shoulder ants, have a preference for sweet substances. In soya plants, these ants play a role in pollinating the flowers. With this fact, Sambueja Sub-district, where this study took place, is very vulnerable to pest attacks on soybean plants. Remember, predatory ants will tend to be abundant if supported by a suitable environment. Environmental conditions play an important role in increasing the effectiveness of pest control, as stated by Blüthgen (2002) and Murage *et al.* (2007). Some ant species have unique characteristics related to prey hunting behavior. For example, *T. melanocephalum* exhibits rapid mobility, resulting in a higher response rate when preying. On the other hand, *S. invicta* has a slower response rate but compensates with the ability to carry larger colonies due to its high abundance in the field, resulting in more prey being captured. This is supported by Johnson and Triplehorn (2004), who noted the diverse feeding habits of ants. Ants have a varied diet, including carnivorous habits where they consume live or dead animal flesh, as well as plants, fungi, plant juices, and honey. Ants in a colony often consume the secretions of other individuals and exchange food between them. In addition, ants also produce exocrine secretions that have various functions, such as attack, defense and communication.

Conclusion

The presence of ants in soya plants can influence pest control. If the presence of ants is high in the field, chemical pest control can be reduced. To maintain the presence of ants, good food availability is required, which can be achieved by providing supplementary food. The presence and number of ants in an ecosystem can be indicators of the overall health of the ecosystem and the presence of other organisms. This is due to the many interactions ants have with various plants and animals. In conclusion, in this study, four ant species were found in soybean fields: *S. invicta*, *O. denticulata*, *T. melanocephalum* and *A. gracilipes*. Each ant had a main nest and transit nests with different trajectories. The highest ant abundance and dispersal were observed in *S. invicta*. *S. invicta* and *A. gracilipes* ants act as predators of soybean pests by preying on the larvae and pupae of leafminer caterpillars. Feed from discarded anchovies attracts ants, so it can be one way to control ant populations in soybean fields.

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Author Contributions

Tamrin Abdullah: Conceived ideas, coordinated research activities, designed the research plan, statistical analysis, prepared the manuscript and final approval. Prihatin Prihatin: Designed research, manuscript writing, statistical analysis, literature search, and final approval. Nurul Wiridannisaa: Literature search, designed research plan, variable assessment method and organized data collection. Putu Eka Irawan: Designed research plan and collected data.

Conflicts of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper

Funding Source

Not applicable

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