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The effect of integrated pest management on *Scirpophaga innotata* population and natural enemies on rice fields in South Sulawesi, Indonesia

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Abstract. *Rahmawasiah, Abadi AL, Mudjiono G, Rizali A. 2022. The effect of integrated pest management on* Scirpophaga innotata *population and natural enemies on rice fields in South Sulawesi, Indonesia. Biodiversitas 23: 4510-4516.* White rice stem borer, *Scirpophaga innotata*, is an important pest on rice plants that needs attention because the population is quite large in Luwu Raya. This pest attacks rice plants at all growth stages and can result in yield losses in rice production. Synthetic insecticides are a common control technique used by farmers to control these pests. The continuous use of pesticides will certainly have a negative impact. Therefore, pursuing effective control strategies and maintaining environmental sustainability is necessary. This study aimed to determine the white rice stem borer population and its natural enemies on rainfed land, and permanent irrigated lands managed conventionally and integrated pest management. The research was carried out using insect sampling techniques and calculating the white rice stem borer population and natural enemies in rice cultivation. In rainfed and irrigated rice fields, rice cultivation was carried out using conventional methods and integrated pest management (in the form of planting refugia and regulating the use of synthetic pesticides). The sampling was carried out on plants from the vegetative phase to the generative phase. The type of insect taken was the white rice stem borer in the form of collecting groups of eggs and larvae. Imago was observed visually and using a farmcop. In addition, the collection of natural enemy insects on the plantation was also carried out. The results showed that the application of the integrated pest management system caused no significant effect on the decline of the white rice stem borer population in both rainfed and permanently irrigated lands in Luwu Raya. The white rice stem borer population was more commonly found in rainfed land than permanently irrigated land. The parasitoids found were *Telenomus rowani*, *Tetrastichus schoenobii* and *Trichogramma japonicum*. The population of *Telenomus rowani* was more numerous than other types of parasitoids. On average, the parasitoid population was more in the land managed by integrated pest management (IPM) application than the conventionally managed land. The predators found on the land were *Oxyopes javanus*, *Agriocnemis femina*, *Conocephalus longipennis*, *Menochilus sexmaculata*, *Ophionea nigrofasciata*, *Micraspis lineata*, and *Paederus fuscipes*. Predator populations were more on land managed with the application of IPM than on land managed conventionally.

Keywords: Parasitoid, predator, white rice stem borer

INTRODUCTION

Rice plant (*Oryza sativa*) is a food crop as an energy source that Indonesian people generally consume. Luwu Raya, one of the regions of South Sulawesi province, has the potential for rice production due to its large agricultural land. Data from the Central Statistics Agency of South Sulawesi (2018), revealed that the total harvested production of Luwu Raya reaches 775,660 tons of dry milled grain with an area of 176,797 hectares of rice harvested. Therefore, rice production in the Luwu Raya area has the opportunity to produce even greater rice. However, on the other hand, pests and diseases are still a risk that must be taken into account in every plant cultivation to increase production according to the target (Estiati 2019). Pests and diseases of rice in Luwu Raya area include stem borer, rat, armyworm, rice bug, brown plant hopper, golden snail, crackle, blast, black ladybug, midrib blight, wild boar, brown spot, and sparrows. Among these, the one that causes considerable damage is the white rice stem borer *Scirpophaga innotata* (Lepidoptera: Pyralidae).

Rice stem borer is one of the main pests in rice cultivation which causes considerable economic losses. Rice stem borer pests attack rice crops from seeding to flowering. Symptoms caused by the stem borer in the vegetative are called *sundep* (pygmy shoots), and those in the generative phase are called *beluk* (empty grain) (Baehaki 2013). The problem of rice stem borer has not been resolved properly, as well as in the Luwu Raya, South Sulawesi area. Based on the data from IP3 OPT Region I Luwu in 2017, the stem borer was found in all districts in the Luwu Raya area. The largest population was in Luwu Regency, with an attack area of 609 hectares, and North Luwu 1035 hectares. The existence of the stem borer is supported by environmental conditions where rainfall in the Luwu Raya area is quite high. The dynamics of the white rice stem borer population are strongly influenced by environmental changes, especially climatic factors (rainfall), irrigation, and natural enemies. The stem borer population not only causes damage to rice crops but also disturbs the society there, especially those near rice fields, because, at high populations, the borer will be attracted by residential light and cause itching.

To date, white rice stem borer control still relies on synthetic pesticides. Intensive synthetic pesticides can support rice productivity by reducing yield losses due to pests. Still, on the other hand, it can damage the ecosystem's natural balance and have various other negative impacts. Furthermore, synthetic broad-spectrum insecticides can kill predators, parasitoids, pollinators, and detritivores that are not targeted by insecticides (Syarief et al. 2018). Therefore, attention to alternative control that is more environmentally friendly is getting bigger to reduce the use of synthetic pesticides.

It is necessary to control pests through integrated pest management (IPM) to overcome these problems. According to Surendra (2019), earlier IPM models are designed from the scientific perspective with a focus on ecological, environmental, and evolutionary aspects of pest management to reduce or prevent economic losses. This new model is expected to guide IPM strategies worldwide to ensure profitability for the growers by developing and implementing sustainable agricultural practices and food security for the growing world population. Integrated pest management is an effective and environmentally friendly pest control technique (Kabir and Rainis 2015). According to Alam et al. (2016), IPM was developed for use as a tool in producing healthy, sustainably grown food. IPM practices can be used for effective pest control in rice agroecosystems.

Apart from the insect pests in the rice field ecosystem, there were various insects useful as both s predators and parasitoids. The existence of these useful insects will be even greater if there are plants that can be used as hosts or food sources. This can be done through habitat manipulation. One example of habitat manipulation in pest control is planting flowering plants as a natural enemy habitat (Saldanha et al. 2019). Ecological engineering in the form of refugia plants acts as a microhabitat of biological agents from pests. Refugia can provide shelter spatially or temporally for natural enemies and support components of biotic interactions in ecosystems such as pollinators. In addition, refugia plants have the potential to support system mechanisms such as improving the availability of alternative food such as nectar, pollen, and honeydew, providing shelter or microclimate used by predatory insects to survive through changing seasons or sheltering from environmental extreme factors or pesticides and providing habitat for alternative hosts or prey (Landis et al. 2000). Planting refugia plants in the bunds are expected to attract the predatory arthropods and parasitoids to come earlier with a fairly high population so that it will be able to curb the development of rice pest populations.

This study aimed to determine the white rice stem borer population and its natural enemies on rainfed land and permanently irrigated managed conventionally and IPM.

MATERIALS AND METHODS

Research time and location

The research was carried out from February to July 2020 in West Malangke District of North Luwu Regency and Lamasi District of Luwu Regency, South Sulawesi Province, Indonesia.

Research methods

The experiment was carried out in rainfed and permanently irrigated rice fields. In the rainfed rice fields area, the sample land was determined in the form of 4 plots of rice fields managed conventionally and 4 plots of rice fields managed with the application of integrated pest management. In rice fields permanently irrigated, 4 plots of sample land of conventional method and 4 plots of integrated pest management were also determined. The area of each sample plot is 2500 m^2. The conventional method is a rice cultivation technique according to the habits of local farmers. On the other hand, the method of implementing integrated pest management is carried out by planting refugia and regulating the use of synthetic pesticides.

Sampling was conducted on plants from the vegetative phase (2 weeks after planting) to the generative phase (2 weeks before harvest). The type of insect taken was the white rice stem borer in the form of collecting groups of eggs and larvae. Imago was observed visually and using a farmcop. In addition, the collection of natural enemy insects in the plantation was also carried out.

The collection of egg groups was done by making a 50 m long transect line on each plot of sample land, both conventionally managed land and with integrated pest management. Each group of eggs obtained from plants on the right and left of the transect line was put into a plastic container with a lid, then labeled and brought to the laboratory for observation of the larvae and imago parasitoids that appeared. The parasitoids obtained were stored in 70% alcohol, and the identification process was carried out. Identification was made based on morphological characters, including body size and color, antenna shape, and wing shape. Sample plants that showed white rice stem borer symptoms were taken for observation, and the number of larvae found was counted. Insects found in the rice clumps were taken using a farmcop which was repeated every week starting two weeks after planting until two weeks before harvesting. In each plot of sample land, 10 clumps of sample plants were determined diagonally. Before using the farmcop, the sample plants were covered with a mica tube measuring 80 cm high and 40 cm in diameter. All insects found on the sample plants were collected and brought to the laboratory for identification.

Statistical analysis

The damage intensity was calculated using the formula:

$$I = \frac{\text{number of symptomatic tillers}}{\textit{total number of tillers observed}} \, x \, 100\%$$

The data obtained were analyzed by an independent T sample test with an accuracy level of 5%.

RESULTS AND DISCUSSION

White rice stem borer egg group

Population fluctuations of egg groups in conventional and IPM fields in permanently irrigated and rainfed rice fields are presented in Figure 1. Egg groups have been found since the age of rice 2 weeks after planting (WAP) in permanently irrigated and rainfed rice fields. In the planting area, very few weeds or grasses grew, which caused the imago borer only to lay eggs on rice plants. The population of egg groups on conventional and IPM fields increased during the vegetative phase and was most abundant at the age of 4 WAP on permanent irrigated land and 5 WAP in rainfed rice fields. This is related to the absence of treatment given by farmers at the beginning of planting, even though cutting the seedling leaves before planting can reduce the population of the borer egg group. According to Beuzelin et al. (2012), reducing rice main crop harvest cutting height from a conventional 40 cm to 20 cm decreased Mexican rice borer infestations in the stubble by 70 to 81%.

The t-test results show that the groups of eggs in the rice fields managed conventionally and IPM were not significantly different. The population of egg groups in rainfed rice fields was quite high because farmers do not pay attention to the imago population before sowing the seeds so that when the plants grow, the imago can immediately lay eggs on the plants. The stocking of rice seeds in nurseries is only carried out if moths are flying so that the eggs laid by the first generation of white rice stem borer are not on plants but on grass or other plants so that the nursery will avoid attacks and the population of the second generation borer will be low. The population of egg groups in the irrigated rice fields was low because the planting was carried out simultaneously, and irrigation arrangements were made during planting (Suharto and Usyati 2016). Manipulation of sowing time can cause harm to pests which are susceptible to extreme air or water temperature, heavy rainfall, non-preferred crop growth stage, and abundance of natural enemies. Time for sowing and planting stage of maize are among the most important factors affecting thrips, aphids, and stem borer (Mahmoud et al. 2021).

The population of white rice stem borer larvae

In rainfed rice fields, the average population of white rice stem borer larvae on conventional land was lower than that of IPM land, which was 0.18 head/clump, and that on IPM land, it was 0.19 head/clump. Many larvae in this crop are due to farmers' high dose of nitrogen application to rice plants. Nitrogen fertilizers affect the growth and development of Lepidoptera, Hemiptera, and Diptera (Butler et al. 2012). High nitrogen content is suitable for larval development and will accelerate larval development (Suharto and Usyati 2016). Furthermore, Israel in Thamrin et al. (2017) reveals that nitrogen fertilizer can stimulate tiller growth, but rice planting with a large number of tillers increases the relative humidity and affects the number of rice stem borer eggs hatch.

In permanently irrigated fields, the average larvae population on conventional land was slightly higher than that on IPM land, which was 0.12 head/clump, and on IPM land, it was 0.10 head/clump (Figure 2). The low population of white rice stem borer larvae on IPM land is caused by several factors, including the use of biological agents, *Beauveria bassiana*, as a substitute for insecticides, which can invest and cause death in larvae. According to Ogah and Nwilene (2017), insect pathogens such as *Metarhizium*, and *Beauveria* are mostly manipulated biological control agents. It is known that the entomopathogenic fungal attack of host insects involves both a direct infection by the fungus and the action of its secondary metabolites (Fan et al. 2012). The low population of larvae in IPM land is also because the area is planted with refugia which can invite the arrival of more parasitoids and parasitize the egg groups present in the crop, thereby reducing the larval population.

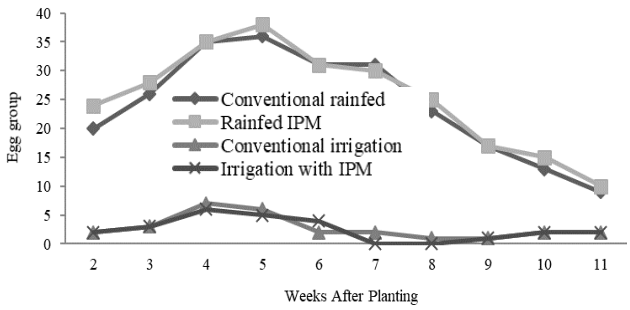

Figure 1. Number of egg groups of white rice stem borer on rainfed and permanently irrigated managed conventionally and IPM

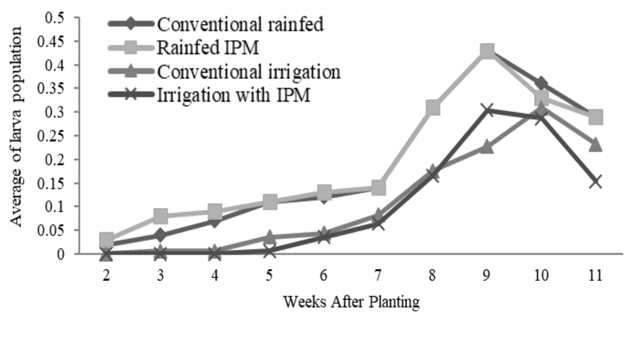

Figure 2. The average population of white rice stem borer larvae in rainfed and permanently irrigated managed conventionally and IPM

The population of white rice stem borer imago

The results of the t-test on the average white rice stem borer imago obtained using a farmcop and visual observations on conventional and IPM fields showed that the results are not significantly different. The population fluctuations of the white rice stem borer imago are shown in Figure 3. The imago population on conventional land was almost the same as that of land managed by IPM because in addition to the same land conditions, the distance between the two is also not too far apart so that the white rice stem borer imago allows it to move around from one area to another. The flight range of the rice stem borer moth is 6-10 km (Suharto and Usyati 2016).

The white rice stem borer imago population in rice cultivation in rainfed rice fields was mostly found at 4 WAP observations. In contrast, that in permanently irrigated rice fields was found at 2 WAP. This is because the rainfall was quite high at that time, which greatly supported the development of these pests. Baehaki (2013) found that the diapause behavior of white rice stem borer caterpillars changes only 25%, and the remaining 75% developed into moths under continuous rain. The population of white rice stem borer imago in rice cultivation on permanently irrigated land was lower than that in rainfed land because on rainfed land, farmers generally only leave the rice stump left over from the harvest in the fields so that it becomes a place for stem borer to diapause. Suharto and Usyati (2016) reveal that white rice stem borer requires diapause or experiences dormancy during the dry season or drought in rice stump.

The intensity of white rice stem borer attack

The results of the t-test showed that the intensity of the white rice stem borer was not significantly different in conventional and IPM fields. In the rainfed rice fields, the intensity of attack on conventional land was slightly lower than IPM land. In contrast, in the rice fields with permanent irrigation, the stem borer intensity on conventional land was similar to that of IPM land (Figure 4). In rainfed rice fields, insecticides are quite intensive on conventional land, so the borer attack intensity was lower than on IPM land. Some insecticides, including Fipronil, Carbofuran, Carbosulfan, Diazinon, Chlorpirifos, Phenthoate, and Quinalphos, were used to control stem borers (Leonard and Rwegasira 2015). Baehaki (2013) stated that the application of insecticides Prevathon and Dimehipo could suppress *sundep* (pygmy shoots) attacks. In permanently irrigated rice fields, the intensity of attack is lower on IPM land due to the application of *Beauveria bassiana* which can control white rice stem borer larvae.

The high intensity of stem borer attacks on rice cultivation in rainfed land was due to the high use of nitrogen fertilizer. The application of high nitrogen fertilizers can increase the intensity of stem borer attacks (Ramzan et al. 2007). According to January et al. (2020), too much nitrogen fertilization can increase stem borer damage. High nitrogen fertilizers cause plant stems to become succulents, so the intensity of stem borer attacks is higher, body weight is greater, and the life cycle is shorter (Lu et al. 2007). The low intensity of stem borer attacks on rice fields that use permanently irrigated compared to rainfed land was because the farmers generally pay attention to planting time. The planting time can affect stem borer; earlier planted rice plants are the most resistant to stem borer (Mohamed 2012). In addition, the low intensity of attacks is also because the farmers generally use organic fertilizers made from rice husks containing silica. Applying materials with high silica contents in rice fields, either as soil incorporated or spray on rice foliage, can also reduce the infestation levels of stem borer (Hendawy et al. 2018). Silica soil amendments could play a role in a refined Mexican rice borer management strategy (Beuzelin et al. 2016). Applying balanced fertilization, including the use of complete NPK fertilizers, so that the needs of plant elements are met and nothing is excessive. Farmers have always used this. According to Suharto and Usyati (2016), K fertilization causes plants to be stronger or healthier, so they are more resistant to borer attacks. Read et al. (2006) stated that potassium fertilizer plays an important role in plant growth and metabolism. Potassium can increase fiber strength and plant quality.

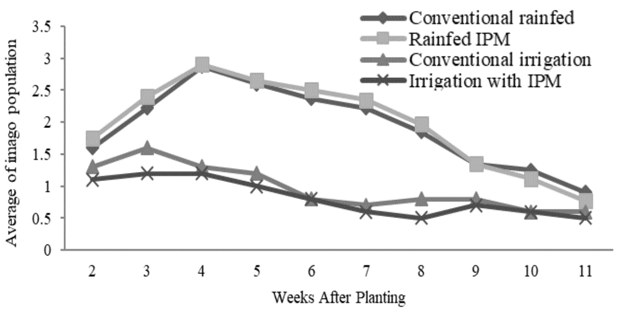

Figure 3. The average population of white rice stem borer imago in rainfed and permanently irrigated managed conventionally and IPM

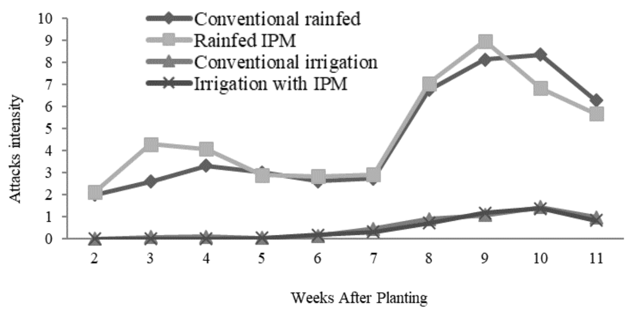

Figure 4. The average intensity of white rice stem borer attack on rainfed and permanently irrigated managed conventionally and IPM

White rice stem borer parasitoid population

The t-test on egg parasitoid populations found in conventionally managed land and IPM show significantly different results. Populations of egg parasitoids are more commonly found in IPM land than in conventionally managed land (Figure 5). This is probably due to the planting of refugia in the form of flowering plants in the rice fields so that there is a habitat for natural enemies, especially parasitoids. Flowering plants can attract natural enemies by providing nectar or pollen (Parolin et al. 2012). According to Rahardjo et al. (2018), habitat manipulation provides suitable habitats for natural enemies. Therefore, it can support conservation activities in maintaining ecosystems in agricultural areas to increase the population of natural enemies, both predators and parasitoids. Eggs of the types of parasitoids were found; *Telenomus rowani*, *Tetrastichus schoenobii*, and *Trichogramma japonicum* (Figure 6). The parasitoid *T. rowani* is more commonly found in plantations, possibly one of the causes due to geographical factors such as the location of rice fields which are only at an altitude of 9 m above sea level. According to Junaedi et al. (2016), Telenomus is the most dominant species in lowland rice cultivation (<200 m asl). The parasitoid *T. rowani* was more often found, probably also because the eggs found are generally small.

Furthermore, the most commonly found parasitoids were *T. japonicum*, and the least was *T. schoenobii*. Many studies show that *Trichogramma* can control Lepidoptera pests by parasitizing their eggs (Ko et al. 2014; Lou et al. 2014). In addition, *Trichogramma* could positively affect yellow stem borer pest control (Tang et al. 2017).

The highest population in the two fields is generally seen at 11 WAP, the final generative phase, where the planting condition was very lush with maximum tillers so that the imago parasitoid preferred for their activities. The population of parasitoids on irrigated land was less than that on rainfed land because there were fewer egg groups in the crop. The low density of rice stem borer eggs affects the speed of parasitoids in searching for these groups of borer eggs (Thamrin et al. 2017).

The predatory population of white rice stem borer in rainfed land

The average population of predators on IPM land was higher than conventional land, both in rainfed rice fields and rice fields that use permanent irrigation (Figure 7). This is presumably due to the reduced use of pesticides on IPM land so that predators are always present in the plantations. According to Naranjo et al. (2015), integrated pest management focuses on protecting natural predators of pest insects. In addition, it is also caused by the planting of refugia in the form of flower plants like zinnia and cosmos flowers around rice fields which can invite the insects to come, including the predators. The existence of refugia can be a shelter or food source for insects. According to Tili et al. (2020), predatory arthropods are mostly found in rice, and refugia is a zinnia plant. Heri et al. (2021) stated that habitat manipulation could increase the number of beneficial insect populations in the short run. Still, it might take time to increase their diversity in an agroecosystem.

The T-test shows that predator populations on conventional land were not significantly different from that of IPM land. Several types of predators were found in both fields, including *Oxyopes javanus* (Figure 8). The spiders in rice plantations can prey on 2-3 insects per day. Therefore, spiders can produce many offspring in a relatively short time to balance the insect pest population (Thamrin et al. 2017). The white rice stem borer predators in the plantations were *Agriocnemis femina*, *Conocephalus longipennis*, *Menochilus sexmaculata*, *Ophionea nigrofasciata*, *Micraspis lineata*, and *Paederus fuscipes*, but the population level was low. Predatory populations on rainfed land were more abundant than the irrigated land because, on rainfed land close to the rice fields, many other crops were also cultivated, such as corn, beans, and plantation crops which can serve as food sources for many insects.

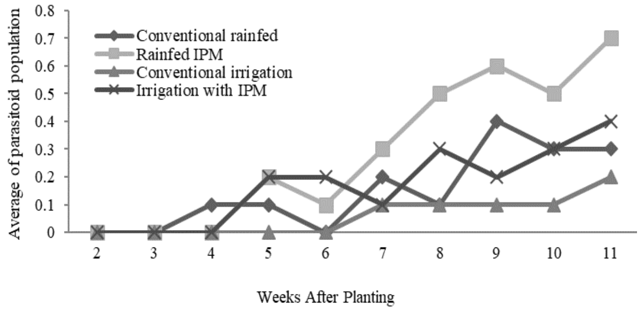

Figure 5. Average population of white rice stem borer egg parasitoid in rainfed rice fields and permanently irrigated managed by conventional and IPM

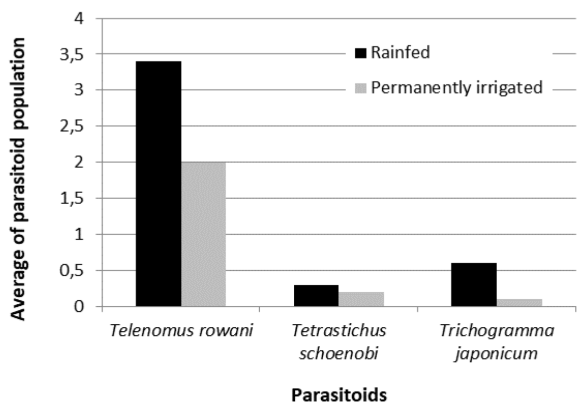

Figure 6. The average population of white rice stem borer egg parasitoids in rainfed and permanently irrigated

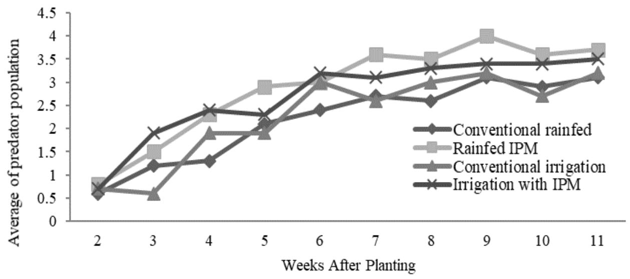

Figure 7. The average population of white rice stem borer predators in rainfed rice fields and permanently irrigated managed conventionally and IPM

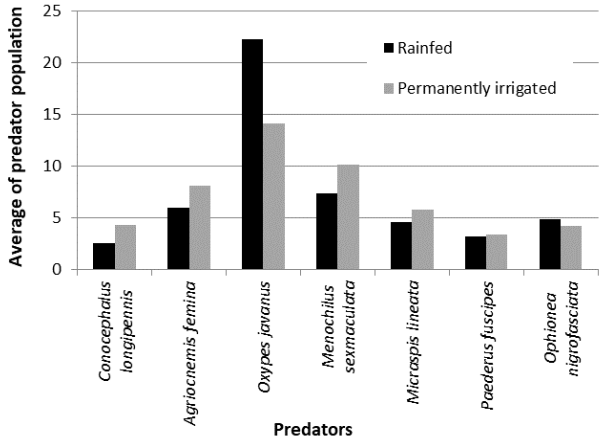

Figure 8. The average population of white rice stem borer predators in rainfed and permanently irrigated managed

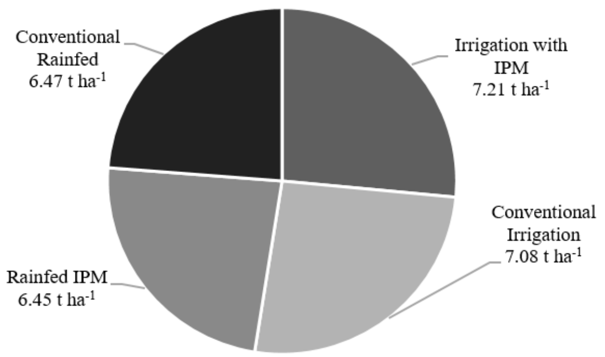

Figure 9. Rice production in rainfed rice fields and permanently irrigated managed conventionally and IPM

Rice production

Rice production in permanently irrigated rice fields was higher on land managed by IPM than the conventional one (Figure 9). IPM land produced 7.21 t ha^{-1}, while the conventional land produced 7.08 t ha^{-1} of rice grain. According to Alam et al. (2016), the advantage of integrated pest management techniques is that rice production increases along with increased cropping system resistance. Babendreier et al. (2020) stated that implementation of the IPM strategy resulted in higher rice yields (2-10%), an increase in natural enemy abundance, and a reduction in insecticide application (1.5 fewer applications). In rainfed rice fields, rice production was slightly higher on conventionally managed land, i.e., 6.47 t ha^{-1}, while on IPM land, the rice production was 6.45 t ha^{-1}. Rice production in permanently irrigated rice fields was higher than in rainfed rice fields due to several factors: 1) the high intensity of white rice stem borer attacks in rainfed rice fields; 2) in permanently irrigated fields, farmers generally pay attention to the use of balanced fertilizers and the presence of irrigation, which is very supportive for maximum rice growth.

In conclusion, the application of an integrated pest management system caused no significant effect on the decline of the white rice stem borer population in both rainfed and permanently irrigated lands in Luwu Raya. The white rice stem borer population was more commonly found in rainfed land than permanently irrigated land. The parasitoids found were *Telenomus rowani*, *Tetrastichus schoenobii*, and *Trichogramma japonicum*. The population of *Telenomus rowani* was more numerous than other types of parasitoids. The average population of parasitoids was higher on land managed with the application of IPM than on land managed conventionally. Predators found on the land were *Oxyopes javanus*, *Agriocnemis femina*, *Conocephalus longipennis*, *Menochilus sexmaculata*, *Ophionea nigrofasciata*, *Micraspis lineata*, and *Paederus fuscipes*. Predator populations were higher on land managed with the application of IPM than on land managed conventionally.

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