Research Article

Determination of Tolerance Threshold Level of Golden Snail (*Pomacea canaliculata*) in Irrigated Rice

Penentuan Tingkat Ambang Toleransi Keong Mas (*Pomacea canaliculata*) pada Padi Sawah

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ABSTRACT

Determination of tolerance threshold of golden snail (*Pomacea canaliculata*) infestation in irrigated rice had been studied at Sumbersari Village, Moyudan District, Sleman Regency, Yogyakarta Special Teritory, in the growing season of June to October 2016. The water depth during the experiment was maintained at 1 cm. The snails of 2−3 cm in length were infested on rice plots at various ages. The snails were infested on rice plots with density rates of (1) 0, 1, 2, 3, 5, 15, 30; (2) 0, 2, 3, 5, 10, 15, 30; and (3) 0, 3, 5, 10, 15, 20, 30 individuals/m^2 at (1) 0 day after planting (DAP), (2) 7 and 14 DAP, and (3) 28 DAP, respectively. These treatments were replicated three times and arranged in the randomized complete block design (RCBD). In this study the tolerance threshold is defined as the highest snail density which causes no significant effect on rice damage and yield loss as compared to control or to the lowest snail density. Therefore, determination of the tolerance threshold was based on the significant difference of damage severity, panicle number per hill, and harvesting dry-weight of rice grain. Results showed that significant rice damage occurred on age of 0, 7, and 14 DAP olds, while on age of 21 and 28 DAP the rice showed no damage. More severe damage occurred to the younger rice. The tolerance threshold values of the snail on rice plots with 1 cm water depth at 0 DAP old was approximately 2 individuals/m^2 while at age of 7 and 14 DAP were approximately 3 individuals/m^2, respectively.

Keywords: *Pomacea canaliculata*, rice, tolerance threshold, yield loss

INTISARI

*Penentuan ambang toleransi serangan keong mas (*Pomacea canaliculata*) pada padi sawah telah dikaji di Desa Sumbersari, Kecamatan Moyudan, Kabupaten Sleman, Daerah Istimewa Yogyakarta dalam musim tanam Juni–Oktober 2016. Kedalaman air selama percobaan berlangsung dikondisikan sedalam 1 cm. Keong berukuran 2−3 cm diinfestasikan pada berbagai umur padi. Keong dengan kepadatan (1) 0, 1, 2, 3, 5, 15, 30; (2) 0, 2, 3, 5, 10, 15, 30; dan (3) 0, 3, 5, 10, 15, 20, 30 ekor/m^2 diinfestasikan berturut-turut pada plot padi (1) saat tanam (0 hari setelah tanaman (HST)), (2) umur 7 dan 14 HST, dan (3) serta umur 21, dan 28 HST. Perlakuan diulang tiga kali dan diatur dalam rancangan* randomized complete block design *(RCBD). Dalam penelitian ini ambang toleransi didefinisikan sebagai kepadatan keong tertinggi yang menyebabkan kerusakan tanaman padi dan kehilangan hasil tidak berbeda signifikan dengan kontrol atau dengan kepadatan populasi terendah. Oleh karena itu nilai ambang toleransi ditentukan berdasarkan signifikansi perbedaan kerusakan tanaman, jumlah bulir per rumpun, dan berat kering panen gabah. Hasil kajian menunjukkan bahwa kerusakan signifikan terjadi pada padi umur 0, 7, dan 14 hari setelah tanam (HST), sedangkan pada umur 21 dan 28 HST padi tidak menunjukkan kerusakan. Kerusakan semakin parah pada padi semakin muda. Pada kondisi kedalaman air 1 cm, nilai ambang toleransi keong mas pada padi umur 0 HST sekitar 2 ekor/m^2 sedangkan pada umur 7 dan 14 HST sekitar 3 ekor/m^2.*

Kata kunci: ambang toleransi, kehilangan hasil, padi, Pomacea canaliculata

INTRODUCTION

The golden snail has been introduced to several Asian countries. The reason for the introduction of the golden snail [*Pomacea canaliculata* (Lamarck, 1822) (Mesogastropoda: Pilidae)] is for economic purposes but unexpectedly it develops into rice pests (Halwart, 1994). Wetland paddy damage was reported in 1995 in only 12 districts in West Java but in 1999 it had expanded to 16 districts and within 3 years the damage had increased from 5 to 170 times (Suharto, 2002). Damage to rice plants in the nursery can reach 100% and after transplanting 10% (Morallo-Rejesus *et al*., 1988).

The golden snails prefer young rice plants and cut the base of the stem so that the plants fall and float on the surface of the water. If the attack is high, stitching seedlings 2−3 times in one growing season, consequently harvest is not simultaneous and the quality of grain is not uniform (Anonymous, 2015). For transplanting systems, the young rice plants up to 15 days after planting (DAP) are susceptible to the snail attacks. For direct seeding system, the paddy is vulnerable to snail attack until 30 days old, then the seedlings are more tolerant (Suharto & Kurniawati, 2009).

Various ways of golden snail control have been developed. Wagiman *et al.* (2015) tested the potential of ducks as predator. Botanical molluscicides include *Deris elliptica* roots were reported to be poisonous to the golden snail but toxicity of the *D. elliptica* is still under the synthetic molluscide namely metaldehyde (Kardinan & Iskandar, 1997). The golden snail is the main pest of rice and the use of molluscicides is increasing rapidly (Horgan *et al.*, 2014). The use of chemical pesticides should be prudent and in the application of integrated pest management (IPM) technology, the application of chemical molluscicides should be based on the economic threshold level.

The Economic Threshold Level is defined as the level of population density that justifies the control action so that the next population does not reach the Economic Injury Level (EIL) (Untung, 1984). According to Dent and Wright (2000) the concept of Economic Threshold has developed and is widely used in the application of IPM which is divided into two groups: subjective Economic Threshold and objective Economic Threshold. The subjective Economic Threshold is a rough Economic Threshold approach which in determining its value is not based on the calculation of EIL but rather based on observations of practitioners or farmers' experiences. The objective Economic Threshold is determined based on the variables of the EIL, the price of the product on the market, the cost of control, the amount of damage caused by one individual of pest, the damage per crop unit, and the proportion of loss resulting from the pest attack. In practice the term of Economic Threshold develops into a Tolerance Threshold (TT), Control Threshold (CT), and others. The Tolerance Threshold in this study is the development of a subjective Economic Threshold normally used in agricultural extention and verbal recommendations. This study aimed to determine the level of golden snail Tolerance Threshold.

MATERIALS AND METHODS

Determination of TT is done by comparing the crop damage intensity and yield loss between the treatment of snail density rates and the control. The study was conducted in Sumbersari Village, Moyudan District, Sleman Regency, Yogyakarta Special Teritory, from June to October 2016. The golden snail used for the experiment was 2−3 cm in length. Rice variety used was the most widely grown by farmers namely Ciherang. Paddy seedlings of 20 days old after seed sowing were used in this study. The experimental plot measuring 1 m×1 m, was planted with 25 hills with a distance of 20 cm×20 cm, and three seedlings per hill. The depth of water was maintaiend consistently as deep as 1 cm.

A single treatment factor of field trial used Randomised Completely Block Design (RCBD) and three replications. The treatment was density rates of golden snails which infested in the experimental plots measuring 1 m × 1 m with different ages of rice plants. The density of the golden snail infested in paddy 0 DAP was 0, 1, 2, 3, 5, 15, and 30 individuals/m^2, at age 7 and 14 DAP was 0, 2, 3, 5, 10 , 15, and 30 individuals/m^2, while at age 21 and 28 DAP was 0, 3, 5, 10, 15, 20 and 30 individuals/m^2. Different population density variations according to plant age were determined based on the susceptibility of rice plants to snail attack and the highest population was determined by 30 individuals as the golden snail population in the field reached 30 individuals/m^2.

The observation parameters is damage intensity per hill and per plot, number of panicles, and grain yield loss. Intensity of damage per hill i.e.

percentage of damaged plants per hill. The intensity of damage per plot is the percentage of damaged hills per plot. The damage intensity is calculated using the following formula:

$$P = \frac{b}{B} \times 100\%$$

where P = percentage of damaged plants per hill or percentage of damaged hill per plot; b = number of infested plants or hills; B = number of rice plants per hill or hills per plot

The number of infested plants was recorded for 5 consecutive days since the day after the snail infestation at 07.00 a.m. The number of panicles per m^2 was recorded at the time of the milky grain stage. Yield was the harvested-dry rice-grains. Loss of yield was the proportion of the difference in yield between the treatment and the control divided by yield of the control. Data analysis and determination of tolerance threshold values such as follows. Analysis of variance (ANOVA) and DMRT α 0.05 was applied for the analysis of damage intensity, number of panicles and yields and yield loss. The golden snail tolerance threshold level was the highest snail density causing rice crop damage and yield loss wich not significantly different from the control or not significantly different with the lowest population density.

RESULT AND DISCUSSION

Intensity of Rice Damage

Intensity of damage to paddy per hill. Up to 5 days after infestation, the number of plants per hill remains as many as three plants. The golden snail infestation on the 0 DAP caused very severe damage within 1− days after infestation (Table 1).

In the paddy fields that are endemic areas of golden snails, throughout the year in the area there is always a golden snail either before, at the time, and or after transplanting rice seedlings. Although the paddy fields are drought the snails are able to survive by diapause (Bunga *et al.*, 2016b). The study of snail infestation at planting time (0 DAP) is a simulation of the threat of rice damage at the beginning of growth. Table 1 shows that if snail attacks occur from planting time, crop damage increases with age (1−5 days) and snail population densities (1−30 individuals/m^2). In just 24 hours 100% of the paddy on plot 1 m × 1 m was eaten up by 30 snails and only 3 days by 5 snails. At 24 hours observation after infestation, the snail densities of 1 and 2 indiviuals/m^2 did not differ significantly with control, then tolerance threshold at age 0 DAP was approximately 2 individuals/ m^2.

Intensity of damage to paddy hill per plot. The number of plants per hill at the age of more than 7 HST had increased. The golden snail infestation on paddy at 7 and 14 DAP old caused damage to the crop, whereas on paddy at the age of 21 and 28 DAP completely undamaged (Table 2). Paddy of 21 and 28 DAP old did not suffer damage to all treatments. This study was in accordance with research conducted by Bunga (2017) which indicates that the snail attacks 0% on paddy at 5 and 6 weeks old. In addition, the water level limits the mobilization of the golden snail. In this study the golden snails just layed their eggs on the rice stalk but did not eat the paddy. In this study the old paddy crops—more than 41 days since seed sowing—were resistant to snail attacks, such as the results reported by Bunga *et al.* (2016b). They stated that feeding rates of juvenile snails (11−20 mm in length) on paddy of 4 weeks old had

Table 1. Damage intensity of rice per hill at infestation date of 0 day after planting (DAP) on various densities of golden snail

Observation dates	Average of damaged rice per hill (%) on various densities of golden snail (Individuals/m^2)						
	0	1	2	3	5	15	30
1	0.00 a	8.00 a	11.11 a	20.44 b	46.67 c	75.11 d	100 e
2	0.00 a	17.33 b	27.56 b	47.56 c	84.44 d	100 d	100 d
3	0.00 a	26.00 b	47.00 c	65.00 d	100 e	100 e	100 e
4	0.00 a	34.66 b	62.22 c	82.22 d	100 e	100 e	100 e
5	0.00 a	44.00 b	74.66 c	95.55 d	100 e	100 e	100 e

Remark: Average values within rows followed by the same letter are not significantly different, ANOVA and DMRT α 0.05

been greatly decreased, while bigger snail (21−30 and 31−40 mm in length) on paddy of 6 weeks old began to decline. Basri (2010) reported that a snail eats 1 seedling/3−5 minutes or 1 hill/15 minutes 1. Previous experiments show that golden snail at density of 1 individuals/m^2 caused damage by 20%, while density of 8 individuals/m^2 caused damage of more than 90% (Basilio, 1991 *cit.* Naylor, 1996). The snail is more active at night than during the day. Feeding activity of the golden snail during the day and night is not significantly different (Bunga *et al.* 2016a).

Field observations showed that rice plants at 14 DAP or 34 days after seed sowing were still susceptible to snail attacks. The impact of the golden snail infestation at 7 and 14 DAP on crop damage (Table 2) was similar to the study on snail infestation at planting time (Table 1). Crop damage increased with increasing snail population density and with obervation time. The hills were attacked 100% within 24 hours after the infestation was demonstrated by the treatment of density of 15 individulas/m^2 at 7 DAP infestation and by 30 individulas/m^2 on 14 DAP infestation. The lowest density of snail population at 7 DAP infestation of 2 individulas/m^2 and at 14 DAP infestation of 3 individulas/m^2 caused 100% paddy hills damage to be achieved at 4 and 5 days after infestation.

Rice plants at 21 and 28 DAP old or 41 and 48 days after seed sowing showed no damage at all due to the golden snail. Up to a population density of 30 individuals/m^2 the golden snail did not attack the paddy, this phenomenon indicated the paddy of 21 DAP old and above being resistant to snail attacks. Transplanting rice plants with 4 to 5 week old seedlings as much as one seed per hill or increasing the number of seedlings per hill reduces rice crop damage and minimizes yield loss due to snail attack (Sanico *et al.*, 2002).

This study used golden snails of 2−3 cm in length. The bigger size and the higher snail density will result in greater damage. Snail with size of 11−20 mm in length inflict damage of 31.67%, while size of 21−30 mm in length cause damage of 67.76% and most damaging size of 31−40 mm causing damage up to 97.38% in just 1 day (Bunga *et al.*, 2016b). According to Teo (2003) potential snail damage depends on water level, plant age and population density. Water depth determines the proportion of damage higher than the age of seedlings and pest density. At a water depth of more than 5 cm, paddy cropping-system by direct seedling, by transplanting seedlings of 21, 30, and 40 days old each suffered from damage of 100, 89.2, 59.7, and 46%, respectively. Damage susceptibility decreases with age of seed. Damage to 21-day-old seedlings by golden snails of 5 individuals/m^2 is not significant when water is dried on saturated soil moisture. Limited moisture conditions immobilize and prevent pests causing severe damage. Drying rice field at the time of planting or use of seeds aged 30 and 40 days with water depth 5 cm the paddy is tolerant to the snail attack.

Table 2. Damaged rice hills on various densities of golden snail and infestation dates at 5 days after infestation

Infestation (DAP)	Days after infestation date	Damaged rice hills/plot (%) on various densities of golden snail (individuals/m^2)						
		0	2	3	5	10	15	30
7	1	0.00 a	37.33 b	42.67 b	56.00 c	80.00 d	100 e	100 e
	2	0.00 a	61.67 b	68.00 b	77.33 bc	97.33 cd	100 d	100 d
	3	0.00 a	84.00 b	92.00 b	100 b	100 b	100 b	100 b
	4	0.00	100	100	100	100	100	100
	5	0.00	100	100	100	100	100	100
14	1	0.00 a	22.66 b	32.00 c	49.33 d	76.00 e	98.66 f	100 f
	2	0.00 a	48.00 b	62.67 b	77.33 bc	93.33 cd	100 d	100 d
	3	0.00 a	68.00 b	84.00 c	96.00 c	98.67 cd	100 d	100 d
	4	0.00 a	78.67 b	96.00 b	100 c	100 c	100 c	100 c
	5	0.00 a	86.67 b	100 c	100 c	100 c	100 c	100 c
	Density	0	3	5	10	15	20	30
21	1	0	0	0	0	0	0	0
28	1	0	0	0	0	0	0	0

Remark: Average values within rows followed by the same letter are not significantly different, ANOVA and DMRT α 0.05

Number of Panicles, Production, and Yield Loss

The density of the snail has a significant effect on the reduction of the number of panicles per hill, the yield, and the loss of yield. The number of panicles and yields decreased with the increasing population density of the golden snail (Table 3). In this study, stitching paddy seedlings was not done. The experimental plots with 100% of damaged hills (Table 1 and 2) might form new tillers, grow and develop to grain, and produce (Table 3). The paddy hills which were cut off by the snails were still able to grow, but its growth was not uniform as in control. The younger the paddy plants were more attacked by the golden snail, and the greater the yield loss. The highest loss of yield was due to the highest snail density (30 individuals/m^2) i.e. on 0, 7, and 14 HST, 60.1, 51.0, and 44.3%, respectively (Table 3).

The number of rice panicles (Table 3) on control treatment was higher than other treatments at 0 DAP. This is because there was no snails. The number of panicle on control (31.33 panicles) was equal to the number of panicles on treatments of snails with 1 and 2 individuals/m^2. The decrease in the number of panicles began to be significant at 3, 15 and 30 individuals/m^2. The golden snail uses the radula to eat the plant tissue on the water surface border so that the broken plant is then eaten (Suharto & Kurniawati, 2009). Young paddy that was not cut off at the growing point, cought grow back by producing new leaves. The yield on the control was not significantly different with the snail treatment of 2 individuals/m^2.

The lowest yield was on the snail treatment of 30 individuals/m^2. The number of pests is used to calculate or measure the intensity of the attack, it can be assumed that one pest contributes to the damage and loss of the result. The snail density of 1 and 2 individuals/m^2 resulted in an insignificant yield loss of 10.8 and 15% but differed significantly with 3 individuals/m^2. This is in accordance with that proposed by Joshi (2007) which said that snails at 3 individuals/m^2 can cause significant yield loss. Density of 3, 5, and 15 individuals/m^2 indicated a loss of yield but not significant between treatments i.e. 26.9, 35.1, and 41.2%. The highest yield loss was shown in the 30 individuals/m^2 treatment which reached 60%. This means that the snail density affects the yield loss. The higher the snail population, the greater the loss of crops.

On the snail infestation at 7 DAP, the number of panicles on control was significantly higher than treatments. Treatments of 2, and 3 individuals/m^2 had an insignificant number of panicles. Treatments of 5, 10, 15 and 30 individuals/m^2 showed a significant decrease in the number of panicles. The infested paddy was able to compensate for the damage by growing new plants then producing panicles and rice grain. The rice yield on control showed significant higher than those on treatments. Snail treatments of 2, 3, 5, 10, 15 and 30 individuals/m^2 were found to be an insignificant decrease in yield. Yield loss on snail treatments of 2 and 3 individuals/m^2 did not significantly different. The infested paddy might be

Table 3. Number of panicle, rice yield, and yield loss on various densities of golden snail and infestation dates

Infestation (DAP)	Parameters	Golden snail density (individuals/m^2)						
		0	1	2	3	5	15	30
0	*) Panicles/hill	31.3 a	30.6 a	29.5 a	26.7 b	26.0 b	24.1 c	21.0 d
	**) Yield (g/m^2)	981.3 a	875.3 a	829.3 ab	717.3 b	637.0 c	576.7 cd	391.7 e
	**) Yield loss (%)	0.0 a	10.8 b	15.5 b	26.9 c	35.1 c	41.2 cd	60.1 e
		0	2	3	5	10	15	30
7	*) Panicles/hill	33.6 a	30.3 b	29.3 bc	27.8 c	25.9 d	24.1 e	22.5 f
	**) Yield (g/m^2)	1,050.0 a	907.7 b	844.3 b	739.7 bc	637.0 cd	591.3 de	512.7 e
	**) Yield loss (%)	0.0 a	13.2 a	19.3 ab	29.3 bc	39.0 cd	43.5 de	51.0 e
14	*) Panicles/hill	36.0 a	31.4 b	29.9 b	26.2 c	26.4 c	24.9 cd	23.6 d
	**) Yield (g/m^2)	1,027.3 a	955.0 a	873.3 b	779.0 c	717.7 c	662.7 cd	570.7 e
	**) Yield loss (%)	0.0 a	7.1 a	14.9 ab	24.1 bc	30.1 cd	35.4 de	44.3 e

Remark: Average values within rows followed by the same letter are not significantly different, ANOVA and DMRT α0.05 for *) untransformed data and for **) transformed data into √(x+1), α0.05

able to produce panicles and grains. Snail densities of 5, 10, 15 and 30 individuals/m^2 resulted in significant loss of yield namely 23.3, 29, 43.5, and 51%. Yield loss can reach more than 50% if the snail density is high (Joshi, 2007).

Number of panicles that were produced on control and treatment showed the higher the density of the snail population, the number of panicles that can grow less. Teo (2003) stated that the attacked paddy produces panicles that does not differ significantly in various cultural techniques. The golden snail attack can reduce the formation of new plants, but in this study the attacked paddy hills cought grow well and capable of producing a lot of panicles. The yield on control plots did not differ significantly with the snail treatment of 2 individuals/m^2, but began to show significance lower with the treatment of 3 individuals/m^2 and the highest loss was showed on 30 individuals/m^2 caused 44%. This result is similar to that proposed by Naylor (1996) that the loss of the result of a snail attack as high as 40%. Pest density affects the amount of damage as a result of lost plant biomass as it is eaten by the number of plant pests in a certain area. Pests that eat leaf meat directly will reduce the area of the leaf that will interfere with leaf area index (LAI) and leaf area duration (LAD) resulting in loss of yield (Waggoner & Berger, 1987).

Determination of Golden Snail Tolerance Threshold

The tolerance threshold value of the golden snail at planting time (0 DAP) is determined by the damage intensity of young paddy. Due to the intensity of the snail attack on the first day after infestation on treatment 1 and 2 individuals/m^2 did not differ significantly with the control, the tolerance threshold value was 2 individuals/m^2. The tolerance threshold value of the golden snail at the age of 7 and 14 DAP is also determined based on the intensity of the attack. Because of the intensity of the snail attack at the lowest density of 2 individuals/m^2 causing significant damage (Table 2), the tolerance threshold value is 3 individuals/m^2. Litsinger and Estano (1993) stated that the snail density of more than 2 individuals/m^2 inflicts greater damage while less than 2 causes less damage.

Tolerance is a representation of the ability of plants to survive against pest attacks without undergoing such a great impact as yield loss (Higley, 2001). The tolerance threshold value of golden snail can be used as a reference in decision making of golden snail control in wetland paddy. The survey showed that in Malaka Regency, East Nusa Tenggara Province, the density of golden snail population at planting paddy reached 3 individuals/m^2 (Bunga, 2017). This means that the pest attack had reached tolerance threshold. If the presence of a golden snail reaches a tolerance threshold, immediate control is carried out in various ways such as picking, using an attractant plant, duck herding or by using a narrower spectrum of molluscicides.

CONCLUSION

The tolerance threshold value of the golden snail on wetland paddy at the planting time (0 DAP) is individuals/m^2, while at 7 and 14 DAP old is 3 individuals/m^2.

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