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Evaluation of different duck varieties for the control of the golden apple snail (*Pomacea canaliculata*) in transplanted and direct seeded rice

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Abstract

This study investigated the potential of ducks for the control of the golden apple snail in irrigated rice. The varieties of duck recommended for the biological control of snail in decreasing preference were William Siam > Taiwan > Mallard > Peking > Muscovy. Cherry Valley, a variety with a bigger body size was not suitable for snail control because of its poor adaptation to rice field conditions. A density of 5–10 ducks ha^{-1} in continuous grazing for a period of 1–2 months significantly reduced the pest density from 5 snails m^{-2} to less than 1 snail m^{-2}. This density of ducks was recommended for biological control of snails in rice. Timely release of ducks was crucial as they damaged young rice seedlings. In transplanted rice, it was appropriate to release the ducks when the seedlings were 4 weeks old. For direct seeded rice, a longer waiting period of 6 weeks was necessary. Numerically, ducks preyed on more snails in transplanted than in direct seeded rice, but the difference was not statistically significant. The increase in plant density under direct seeding probably reduced the browsing efficiency of the ducks. This difference would be expected to diminish under prolonged grazing. It is suggested that ducks were an effective biological control agent against the golden apple snail.

Keywords: Biological control; Golden apple snail; Ducks; Irrigated and direct seeded rice

1. Introduction

The golden apple snail (*Pomacea canaliculata*) is now a major rice pest in Asia (Hirai, 1988; Halwart, 1994a; Jambari et al., 1993; Morallo-Rejesus et al., 1990). The snail, indigenous to South America, was introduced into Taiwan from Argentina for commercial production in the 1980s (Mochida, 1991). From Taiwan, the snail was distributed to developing countries to help the rural poor earn additional income through backyard rearings (Anderson, 1993) and to supplement protein in their diets (Matienzo, 1984). The snail was introduced without prior studies on market demands or its impact on the ecosystem (Acosta and Pullin,1989). The snail was cultured indoors, but when market response was poor, many snail farming projects were abandoned. In many instances, the snails escaped and ravaged the rice crop with losses running into millions of dollars (Naylor, 1996). Following the outbreaks of the new rice pest, pesticides for effective snail control were not available, so chemicals were selected arbitrarily and used abusively causing excessive environmental pollution and hazards to non-target organisms. Eventually, an integrated pest management concept was adopted to replace the chemical-oriented control program (Rondon and Sumangil, 1989; Teo, 1999a). The new approach emphasized environmentally friendly control measures such as the use of natural enemies, biopesticides (Suryanto et al., 1999) and attractants (Teo, 1999b). Under the context of biological control, ducks (Gallebu et al., 1992; Pantua et al., 1992), fish (Halwart, 1994b; Jambari and Suryanto, 1999) and insects (Barrion et al., 1997) have been tested as biological control agents of the golden apple snail. Of these, ducks were found effective and practical under rice ecosystem conditions. At a density of 8–10 Mallard ducks per 100 m^{-2}, the snail (*P. canaliculata*) population density decreased 79–84% (Vega et al., 1992). However, the potential of ducks for the biological control of the golden

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apple snail has not been studied in greater detail. The paper presents the results of an investigation of biological control of the golden apple snail with ducks. The objectives of the study were to provide guidelines for the adoption of biological control of snails with ducks in irrigated rice.

2. Materials and methods

2.1. General

The varieties of duck used in the trials were Mallard, William Siam (a cross of Mallard × Khaki Campbell), Taiwan, Peking, Cherry Valley, Muscovy and Khaki Campbell. The ducks were 2 yr of age, procured from the Veterinary Department. Golden apple snail were foreign to them and so snails were introduced to the ducks until they found the pest palatable. However, the variety Muscovy failed to develop a taste for golden apple snail even after 3 months. Thus, they were replaced by a flock of Muscovy owned by a farmer and known to feed on the golden apple snail. These ducks were raised from young in areas infested with golden apple snail. Each experimental unit consisted of a fenced 7 m × 7 m plot filled with water to a depth of 5–8 cm. A small shade made of coconut fronds was erected in each plot for sheltering the ducks. The ducks were released into the plots 1 day after the snails were introduced into the plots. The ducks were provided with commercial-feed daily at 75 g duck^{-1} divided into two servings, morning and late afternoon. The ducks were not starved in any of the trials. Any snail in the plots were eliminated by applying tea seed powder, a molluscicide, at a dose higher than the recommended rate of 51 kg ha^{-1} under a water depth of 5 cm 4 days before the trial commenced. This was repeated at the end of the trials in (ii) and (iii) for collecting remaining snails which may be missed during recording by handpicking. The dead snails were collected and recorded the following 4 consecutive days.

(i) *Snail consumption per duck*. The objective of the trial was to investigate the predation potential of each individual duck variety. A randomized complete block design was used with three replications consisting of one duck per replicate placed in a pen (1 m × 1 m × 0.5 m). The duck was given 150 snails with an average shell height of 2.5 cm. The ducks were fed with commercial feed at 100 g duck^{-1}. The duration of the experiment was 2 days. After the first day had lapsed, the number of snails consumed by ducks was recorded and the snails and feed were replenished to the initial quantity. Recordings were repeated at the end of the second day. Two sets of data were obtained and the means of these data were used in the analysis of variance. The data were log transformed prior to the analysis.

(ii) *Predation potential of different duck varieties*. A factorial, randomized complete block design was adopted with three replications consisting of 28 treatments from the combination of seven varieties of ducks and four densities of snail. The densities of the snail were 0.3, 1.0, 3.0 and 5.0 m^{-2}. The ducks were released into the plots at 3 ducks plot^{-1} and were allowed to graze for a period of 7 days. On the eighth day, they were removed from the plots and the water was immediately drained off to facilitate collection of the remaining snails. The data were expressed in percentage prior to the analysis of variance.

(iii) *Optimum density of ducks for biological control of snail*. The duck variety, William Siam, with an outstanding performance in trial (ii) was used in the study. A 4 × 5 factorial, randomized complete block design was adopted with four densities of snail and five densities of ducks replicated 3 times. The densities of snail and duck were 0.3, 1.0, 3.0, 5.0 m^{-2} and 1, 2, 3, 4, 5 plot^{-1}, respectively. The ducks were allowed to graze in the plots for 5 days and on the sixth day, they were removed from the plots and the water was drained to expose snails for handpicking and recordings. Like in (ii) the data were expressed in percentages prior to the analysis of variance.

(iv) *Biological control of snail with ducks in farmers' fields*. The trial was conducted in two locations. In Location A, 80 mature ducks of the variety William Siam were given to the farmers at 10 ducks farmer^{-1}. In Location B, each farmer was given 25 ducklings. A total of 20 households participated in the program. However, only 233 ducks were reared up because of poor husbandry and the presence of natural predators. Before the trial commenced, 15 random 1 m-quadrats ha^{-1} were used to estimate the population of the snail in both locations. The procedure was repeated weekly until the pest population density dropped to < 1 snail m^{-2}. The egg masses were also recorded before and after the trial by collecting and counting the number of clusters in a 15 min walk. This was repeated weekly.

(v) *Damage in rice seedlings at different ages by ducks*. A randomized complete block design with two replications was used to assess the damage by ducks to rice seedlings of different ages. Direct seeded and transplanted rice seedlings were planted in succession to produce a 1, 2, 3, 4, 5 and 6 weeks old plants in the plots. William Siam ducks were released into the plots at 2 ducks plot^{-1} and allowed to graze for 7 days. On the eighth day the ducks were removed from the plots and the damage was recorded by counting the number of missing plants in the rows of the transplanted seedlings. For direct seeded rice, 1 m^2 grids with a total area of 49 m^2 were used. The damage was expressed in percentage over the 49 m^2 plot^{-1}. The data were analyzed using simple linear regression.

(vi) *Snail predation by ducks in direct seeded and transplanted rice*. A randomized complete block design with four replications was used. The plots were planted with rice by direct seeding and transplanting method. The snails were scattered into the plots when the seedlings were 6 weeks old at 3 snails m^{-2} totalling 147 snails $plot^{-1}$. This was followed by the release of William Siam ducks into the plots at 2 ducks $plot^{-1}$ the following day. The ducks were allowed to graze in the plots for 7 days. After this period, the ducks were removed from the plots and papaya (*Papaya carica L.*) leaves, a potent snail attractant (Teo, 1999b) were placed in the four corners of each plot to facilitate the collection of snails not preyed on by ducks. Tea seed powder was not used to kill the remaining snails because it was difficult to hand-pick the dead snails when the crop's canopy is closing up. The snails attracted to papaya leaves were recorded daily for a period of 4 days.

3. Results and discussion

(i) *Snail consumption per duck*. There was no significant difference in the number of snails consumed among the varieties Taiwan, Khaki Campbell, William Siam, Mallard, and Muscovy (Table 1). However, Taiwan, Khaki Campbell and William Siam consumed a quantity significantly higher than the variety Cherry Valley ($F = 3.43$; 6,12 d.f.; $P = 0.03$). Cherry Valley had an average body weight of 2.8 kg, the biggest among the flock yet it consumed the smallest number of snails. The variety William Siam and Taiwan weighed 1.70 and 1.20 kg, respectively, but the quantity they consumed was significantly higher than Cherry Valley. The number of snails consumed in decreasing order was William Siam > Taiwan > Khaki Campbell > Muscovy > Mallard > Peking > Cherry Valley.

(ii) *Predation potential of different duck varieties*. William Siam consumed the greatest number of snails which was significantly more than the rest except for Taiwan ($F = 5.81$; 6, 54 d.f.; $P = 0.0001$). Again, Cherry Valley consumed the smallest number of snails but was not significantly different from Muscovy (Table 2). Cherry Valley, a broiler, was not adaptable to wet conditions. Because of its heavier weight, its movement was slow and it often got stuck in the mud when the volume of water was insufficient to carry its weight. Peking was also a broiler with a body weight of 2.6 kg but it performed significantly better than Cherry Valley. William Siam and Taiwan appeared to be more active. They grazed more often than the other varieties. Their smaller size and lighter body weight enabled them to move faster and browse with greater coverage. Except for Cherry Valley, the rest of the varieties were suitable for the biological control of the golden apple snail in rice fields but the preferred varieties were William Siam, Taiwan and Mallard. In the trial, the ducks were allowed to graze in the plots for 7 days only. If grazing time was prolonged, the percentage of snails preyed upon by each variety would be expected to increase correspondingly. The difference in the quantity of snails consumed between cage and field trial could probably be attributed to the behavioral differences of the varieties of duck under captivity.

Table 1
Number of snail consumed by an individual duck

Variety of duck	Ave. wt. (kg)	# snails consumed[a] $n = 3$
William Siam	1.70	124.0 ± 14.12a
Taiwan	1.20	123.0 ± 1.39a
Khaki Campbell	1.80	96.0 ± 1.26a
Muscovy	2.50	46.0 ± 4.10ab
Mallard	1.85	45.0 ± 4.95ab
Peking	2.60	36.0 ± 2.90ab
Cherry Valley	2.80	17.0 ± 3.59b

[a] Means of three replicates; any two means with a common letter are not significantly different with each other by DMRT at the 5% level. Analyses were conducted on log transformed data.

Table 2
Predation potential of different duck varieties under field conditions

Duck variety	Ave. wt. (kg)	% snail preyed[a] (overall densities)
William Siam	1.60	98.2 ± 2.27a
Taiwan	1.30	90.8 ± 7.59ab
Mallard	1.65	75.4 ± 16.96bc
Peking	2.70	72.5 ± 7.35bc
Khaki Campbell	1.65	71.8 ± 14.73bc
Muscovy	2.40	67.2 ± 12.97cd
Cherry Valley	2.75	52.3 ± 18.73d

[a] Means of three replicates; any two means having a common letter are not significantly different from each other by DMRT at the 5% level.

There was no significant difference in predation between snail densities ($F = 0.54$; 3, 54 d.f.; $P > 0.05$) and its interaction with the different varieties of duck ($F = 0.33$; 18, 54 d.f.; $P > 0.05$). Table 3 shows the percentage of snail preyed upon by ducks under different pest population densities. The ducks consumed over 70% of the snails at either low or high population densities. The ducks were equally good in consuming snails either in high or in low pest population densities.

(iii) *Optimum density of ducks for snail control*. There was a significant difference in the percentage of snails consumed by William Siam ducks at different pest population densities ($F = 6.99$; 3, 38 d.f.; $P = 0.0007$) (Table 4). The interaction between duck and pest population density was not significant ($F = 0.58$; 12, 38 d.f.; $P > 0.05$). At 0.3 snail m^{-2}, the percentage of snails consumed by ducks was not significantly less than at 5 snails m^{-2}, indicating that the ducks were good in searching for prey

Table 3
Percentage of snails preyed upon by different varieties of duck under different pest population densities

Snail density (no. m^{-2})	% preyed upon[a] (overall densities)
0.3	71.4 ± 13.64
1.0	73.8 ± 11.49
3.0	77.6 ± 10.29
5.0	79.1 ± 10.92

[a]Means of three replicates and there were no significant differences in the % of snails preyed upon.

Table 5
Reduction of snail population. densities and snail egg masses following the introduction of ducks for grazing in each location

	Snails population/15 min walk		No. of egg masses/15 min walk	
Week	Location A	Location B	Location A	Location B
1	5.3	5.5	98	130
2	2.8	4.8	30	28
3	1.2	4.0	10	21
4	0.2	3.2	2	10
5	0.0	2.1	1	3
6	0.2	1.5	0	2
7	0.1	0.5	2	0
8	0.0	0.2	0	1

at sparse population densities. The highest percentage of snails consumed by ducks occurred at a pest population density of 3 snails m^{-2}. This was significantly higher than all the other densities. The quantity of snails consumed by ducks began to plateau at a pest density of 5 snails m^{-2}.

Snail consumption increased as duck density increased but the number of snails consumed per duck decreased due to competition for prey (Table 4). The mean number of snails consumed by 1, 2, 3, 4 and 5 ducks was 60.9, 75.3, 87.2, 90.2 and 96.3 snails, respectively. The mean number of snails consumed per duck in the same sequence was 60.9, 37.7, 29.1, 22.6 and 19.3 snails. At a density of 1 duck $plot^{-1}$, the percentage of snails consumed by ducks was significantly less than all the other densities ($F = 17.69$; 4, 38 d.f.; $P = 0.0001$). At 2 ducks $plot^{-1}$ the quantity consumed was significantly greater than one duck per plot but significantly less than 3, 4 and 5 ducks $plot^{-1}$. Thus, the optimum density for a plot size of 7 m × 7 m was 3 ducks $plot^{-1}$ or 612 ducks ha^{-1}. However, it is not possible for a farmer to keep such a big flock of ducks because of the cost of maintenance. Farmers would have to feed their ducks with commercial feed when the paddy field is dry and without snails. The farm size of most rice farmers in Sabah is in the range of 1–2 ha. A small number of ducks in continuous grazing might help to keep the snail population in check.

(iv) *Biological control of snail with ducks in farmers' fields*. The snail densities in both areas before the trial commenced ranged from 2 to 18 snails m^{-2} with an average of 5.6 snails m^{-2} (Table 5). The size of the snails in each quadrat was quite variable, ranging from 0.5 cm in height to 3.0 cm with an average of 2.0 cm. In Location A, with a density of 8 ducks ha^{-1}, the pest density was less than 1 snail m^{-2} after 4 weeks. In Location B with a lower density of 5 ducks ha^{-1}, it took about 7 weeks to reduce the pest density to less than 1 snail m^{-2}. In Location B, the time taken was longer not because of fewer ducks released in the area but due to the presence of natural predators (dogs) which disturbed the ducks grazing in the field. There was a significant corresponding decrease in the number of snail egg masses produced following a reduction in the pest density (Table 5). In Location A, there were very few egg masses after 4 weeks. The same efffect was noticed in Location B on the seventh week. The pest population density was still below 1 snail m^{-2} when census was taken 5 months after the trial. Thus at a density of 5–10 ducks ha^{-1}, it was

Table 4
Percentage and number of snails preyed upon by William Siam ducks at different densities of ducks and snails

Snail density (no. m^{-1})	No. of snails consumed at different no. ducks $plot^{-1}$ ($n = 3$)[a]					Mean (no.)	Mean (%)
	1	2	3	4	5	$n = 15$	$n = 15$
0.3	5.7 ± 3.8	9.0 ± 4.3	12.7 ± 8.0	13.0 ± 9.9	14.3 ± 5.2	10.9 ± 2.2	64.1 ± 12.9b
1.0	23.3 ± 21.1	30.7 ± 3.8	37.3 ± 25.4	38.3 ± 10.0	40.7 ± 14.1	34.1 ± 4.8	69.6 ± 11.3b
3.0	103.0 ± 45.3	107.7 ± 43.7	129.3 ± 31.0	131.3 ± 19.9	133.3 ± 19.0	120.9 ± 9.7	82.2 ± 6.6a
5.0	111.7 ± 52.7	153.7 ± 119.7	169.3 ± 76.5	178.0 ± 42.4	197.0 ± 32.3	161.9 ± 21.2	66.1 ± 8.7b
Mean (no.) ($n = 12$)	60.9 ± 31.8	75.3 ± 40.7	87.2 ± 43.3	90.2 ± 44.5	96.3 ± 48.2	82.0	
Mean (%) ($n = 12$)	49.1 ± 10.5c	62.9 ± 8.3b	77.0 ± 9.7a	79.2 ± 8.2a	84.6 ± 5.5a		70.5
# Consumed $duck^{-1}$	60.9	37.7	29.1	22.6	19.3		

[a]Means of three replicates; any two means having a common letter in the column and row are not significantly different from each other at the 5% level by DMRT.

Table 6
Percent damage by ducks of rice seedlings at various ages

Seedlings' age (week)	Transplanted seedlings[a]	Direct sowing seedlings[a]
1	55.7	95.0
2	24.0	50.0
3	2.1	9.9
4	0.6	5.0
5	0.2	3.0
6	0.2	0.5

[a] Means of two replicates.

possible to maintain the snail population on the low side if the ducks were allowed to graze for a period of 1–2 months.

(v) *Damage in rice seedlings at different ages by ducks*. In general, younger seedlings were more susceptible to duck damage (Table 6). Direct seeded rice when 1 week old suffered 95% damage while transplanted seedlings of the same age incurred only 55.7% damage. In the beginning of the third week, the seedlings became more tolerant to duck damage. When 4 weeks old, the transplanted and direct seeded rice incurred 0.6% and 5.0% of damage, respectively. Since the damage in transplanted seedlings when 4 weeks old was insignificant, it was suitable to release ducks into the field at this age.

At 4 weeks old the direct seeded rice still suffered 5% damage over a 7 day period. If the grazing time was prolonged, greater damage was expected. Thus for direct seeded rice, the more appropriate time to release ducks into the field was 6 weeks. Regression analysis showed that the fitted line for transplanting was $y = 48.84 - 10.01x$ with $R^2 = 0.69$. There was strong evidence that damage in rice seedlings by ducks was related to age ($F = 12.92$; 1, 4 d.f., $P = 0.05$). As seedlings' age increased, damage decreased. The fitted line for direct seeding was $y = 89.08 - 17.67x$ with $R^2 = 0.76$ which exhibited a similar damage pattern ($F = 12.53$; 1, 4 d.f., $P = 0.05$).

(vi) *Snail predation by ducks in direct seeded and transplanted rice*. The results showed that there was no significant difference in the number of snails consumed by ducks in between transplanted and direct seeded rice ($F = 6.17$; 1, 3 d.f.; $P = 0.08$). The mean number of snails preyed upon by ducks in transplanted and direct seeded rice was 142.3 and 110 snails, respectively. The number of snails consumed under transplanting was higher because in transplanted rice, the plants were laid out in rows with alleys wide enough for ducks to browse through. In direct seeded rice, the plants were spaced at random, and it was difficult for the ducks to forage extensively. The zig-zag positions of the direct seeded plants may have hindered the movements of the ducks and reduced their browsing efficiency. Mamat et al. (1999) reported that under direct seeding, the ducks seemed to feed on snails found along the bunds as there was limited swimming space in the midst of the direct seeded rice. If grazing time was prolonged, the difference would be expected to diminish. Biological control of snail is highly recommended for both transplanted and direct seeded rice.

4. Conclusion

Ducks were proven effective for the biological control of the golden apple snail. They could prey equally well under low and high pest population densities. The varieties of duck recommended for biological control of snails include William Siam > Taiwan > Mallard > Peking > Khaki Campbell > Muscovy in decreasing preference. Cherry Valley, a variety with a bigger body size and a heavier weight, was not recommended for biological control of snail because of its poor adaptation to rice field conditions. A density of 5–10 ducks ha^{-1} in continuous grazing was recommended for biological control of snails in rice. A longer duration for grazing was available during the fallow period that lasted for a few months. The farm size of most small-scale farmers ranges from 1 to 2 ha. In Sabah, the farms adjoin one another thereby substantially increasing the hectares of rice available to the ducks. A small number of ducks kept by one household may be sufficient to suppress the snail population at a tolerable level. A large flock would soon deplete the snail population which would create a burden to the farmers when they have to feed their ducks with commercial feed. Thus, the prey population should exist at a certain density which could sustain the population of the predator.

Timely release of ducks into the field was crucial because the ducks may damage young rice seedlings. If the transplanting planting method was used, the ducks should not be released until the seedlings were 4 weeks old. For direct seeded rice, a waiting period of at least 5 weeks was necessary. At 6 weeks old, direct seeded rice was highly tolerant to duck damage.

The percentage of snails preyed upon by ducks was higher in transplanted than in direct seeded rice. The ducks could more easily browse the alleys of transplanted rice than direct seeded rice. This does not mean that biological control of snails with ducks was not applicable in direct seeding planting method. It means rather that a longer grazing time may be necessary in direct seeded rice. There are drawbacks in the biological control of snails with ducks. Natural predators such as dogs were a nuisance to the ducks released in the field. Often, the dogs would attack the ducks. Also, in some districts, it was not possible for farmers to keep ducks for grazing because the farmers tend their farms only during the planting season. When applied correctly, ducks may be an efficient biological control agent for the golden apple snail.

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References

Acosta, B.O., Pullin, R.S.V. (Eds.), 1989. Environment Impact of the Golden apple snail (*Pomacea* spp.) on Rice Farming Systems in the Philippines. International Centre for Living Aquatic Resources Management, Manila, Philippines.

Anderson, B., 1993. The Philippines snail disaster. The Ecologist 23, 70–72.

Barrion, A.T., Jackson, R.R., Schoenly, K.G. 1997. Biology and laboratory predation of *Dindymus pulcher* Stal (Hemiptera:Pyrrhocoridae) on golden apple snail in the Philippines. In: International Workshop on Ecology and Management of the golden apple snail in Rice Production in Asia. Thailand, June 16–19.

Gallebu, A.U., Jover, P.C., Bongolan, F.F., 1992. Integration of ducks to lowland culture as biological control of the golden apple snail. Philippine J. Crop Sci. 17 (Suppl. 1), 27.

Halwart, M., 1994a. The golden apple snail *Pomacea canaliculata* in Asian rice farming systems: present impact and future threat. Int. J. Pest Manage. 40, 199–206.

Halwart, M. 1994b. Fish as biocontrol agents in rice — the potential of common carp *cyprinus carpio* (L) and Nile Tilapia *Oreochromis niloticus* (L). Margraf Verlag, 169pp.

Hirai, Y., 1988. Apple Snail in Japan — the present status and management. J.A.R.Q. 22 (3), 161–165.

Jambari, H.A., Ismail, A., Esa, Y.M., Wong, S.W., Ibrahim, I., Lat, H. L. 1993. Interception and control of golden apple snail (*Pomacea* spp.) in Malaysia. In: Proceedings of the Third Congress of Medical and Applied Malacology. Sydney, Australia.

Jambari, H.A., Suryanto, E. 1999. Fish as biological control agent of golden apple snails—prospects and challenges. In: Proceedings of the Synposium on Biological Control in the Tropics. MARDI Training Centre, Serdang, Malaysia, 18–19 March.

Mamat, N., Booty, A., Bakir, A.H., Bidin, Z. 1999. Controlling golden apple snail, *Pomacea* sp., using ducks, *Anas platyrhynchos*. In: Proceedings of the Symposium on Biological Control in the Tropics. MARDI Training Centre, Serdang, Malaysia, 18–19 March.

Matienzo, L.H., 1984. Wilson Ang's big foot snails. Greenfields 14, 24–29.

Mochida, O., 1991. Spread of fresh water snails *Pilidae mollusca* from Argentina to Asia. MICRONESICA 3, 52–62.

Morallo-Rejesus, B., Saysboc, A.S., Joshi R.C. 1990. The distribution and control of the introduced golden apple snail (*Pomacea* sp.) in the Philippines. In: Introduction of Germplasm and Quarantine Procedure. PLANTI, Kuala Lumpur, Malaysia, pp. 213–224.

Naylor, R., 1996. Invasion in agriculture: assessing the cost of the golden apple snail in Asia. Ambio 25 (7), 443–448.

Pantua, P.C., Mercado, S.V., Lanting, F.O., Nueva, E.B., 1992. Use of ducks to control golden apple snail *Ampullarius-canaliculata* in irrigated rice. Int. Rice Res. Newslett. 17 (1) 27.

Rondon, M.B., Sumangil, J.P., 1989. Integrated pest management for golden kuhol. In: Workshop on Environmental Impact of Golden Snail (*Pomacea* spp.) on Rice Farming System in the Philippines. Freshwater Agriculture Centre, Central Luzon State University, Munoz, Nueva Ecija, November, 9–10.

Suryanto, E., Jambari, H.A., Sajap, A.S., Ahmad, F.H. 1999. Field trial of leaf powder of *Peltophorum pterocardium* against golden apple snail in rice. In: Symposium on Biological Control in the Tropics. MARDI Training Centre, Serdang, Selangor, Malaysia, 18–19 March.

Teo, S.S. 1999a. Control of the golden apple snail in irrigated rice by integrated approach in Sabah. In: The Fifth International Conference on Plant Protection in the Tropics. Kuala Lumpur, Malaysia. 15–18 March.

Teo, S.S. 1999b. Control of the golden apple snail (*Pomacea* spp.) by handpicking using herbage as attractants. In: Proceedings of the MCB-MAPPS Plant Protection Conference'99 on "Sustainable Crop Protection Practices in the Next Millennium". Kota Kinabalu, Sabah, Malaysia, 2–3 November.

Vega, R.S.A., Villancio, V.T., Mendoza, P.A., Limosinero, R.L., Mendoza, T.C., 1992. Agro—economic evaluation of non–chemical control method against golden apple snail (*Pomacea canaliculata*) in irrigated lowland rice. Philipp. J. Crop Sci. 16 (Suppl. 1) 9.