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Bagworm (*Pteroma pendula*) Infestation of Sago Palm (*Metroxylon sagu* Rottb.) in Leyte, Philippines

Masanori Okazaki[1,*], Sonoko Dorothea Kimura[2], Lina B. Suzette[3], Masato Igura[4], Marcelo A. Quevedo[5], Tetsu Ando[6], Toyohei Saigusa[7] and Koyo Yonebayashi[1]

[1] Faculty of Bio-Resources Environmental Science, Ishikawa Prefectural University, 1, Suematsu, Nonoichi, Ishikawa, 921-8836 Japan

[2] Graduate School of Agriculture, Tokyo University of Agriculture and Technology, 3-5-8, Saiwaicho, Fuchu, 183-8509 Japan

[3] Department of Agronomy and Soil Science, Visayas State University, Baybay, Leyte, Philippines

[4] National Institute of Agro-Environmental Sciences, 3-1-3, Kannondai, Tsukuba, 305-8604 Japan

[5] Philippine Root Crop Research and Training Center (PhilRootcrops), Visayas State University, Baybay, Leyte, 6521-A, Philippines

[6] Institute of Symbiotic Science and Technology, Graduate School of Bio-Applications and Systems Engineering, Tokyo University of Agriculture and Technology, 2-24-16, Nakacho, Koganei, 184-8588 Japan

[7] Faculty of Agriculture, Kyushu University, 6-10-1, Hakozaki, Higashi, Fukuoka City, Fukuoka, 812-8581 Japan

Abstract The infestation of bagworm larvae on sago palm (*Metroxylon sagu* Rottb.) applied with two types of urea fertilizer (50 to 100 kg N ha^{-1}), common and slow-release, in an experimental field (6 rows of 5 plots running east to west: A, B, O, C, D, and E) in Leyte, Philippines, was investigated in 2008 and 2010. The bagworm was identified as *Pteroma pendula* Joannis and its related species based on the appearance and the venation of the fore and hind wing of the male adult. The sago palms infested by bagworm ranged from 64 to 100 % of all sago palms from the A to the E row in the experimental field in 2008. Application of urea fertilizer, both common and slow-release, resulted in increasing, although not significant, bagworm infestation. The percentage of infested sago leaves of the spiny sago palm to total leaves of the spiny sago palm was 89 %, which was different from those of non-spiny sago palm (83 %) in 2008. In 2010, the infested sago leaves were found in the spiny sago palms only. The spiny sago palms in the E1 plot (located on the western end of row E) had 6 and 5 infested living leaves, which was 38.5 to 40.0 % of all living leaves of the sago palms. A mono-culture plantation, with limited plant species, has the same kind of pest problem and requires risk management because of the scarcity of natural enemies and the outbreak of bagworm.

Key words: bagworm, common urea fertilizer, Philippines, slow-release urea fertilizer

ミノガによるサゴヤシの食害

岡崎正規[1]・木村園子ドロテア[2]・Suzette B. Lina[3]・井倉将人[4]・Marcelo A. Quevedo[5]・安藤哲[6]・三枝豊平[7]・米林甲陽[1]

[1] 石川県立大学生物資源環境学部, 921-8836 石川県野々市市末松1

[2] 東京農工大学大学院農学研究院, 183-8509 東京都府中市幸町 3-5-8

[3] Department of Agronomy and Soil Science, Visayas State University, Baybay, Leyte, 6521-A, Philippines

[4] 農業環境技術研究所, 305-8604 茨城県つくば市観音台 3-1-3

[5] Philippine Root Crop Research and Training Center, Leyte State University, Baybay, Leyte, 6521-A, Philippines

[6] 東京農工大学大学院生物システム応用科学府, 184-8588 東京都小金井市中町 2-24-16

[7] 九州大学農学部, 812-8581 福岡県福岡市箱崎 6-10-1

要約　フィリピン・レイテにおいて、通常の尿素肥料および緩効性尿素肥料を50あるいは100 kg N ha^{-1}として施用したサゴヤシ実験圃場（管理のために圃場を6列に区分し、1列に5プロットを配した）に発生したミノガの幼虫による食害を2008年および2010年に調査した。本ミノガは、前翅および後翅の脈相、前翅の11本の翅脈と中脈M1の存在、後翅の7本の翅脈および後翅中室が閉ざされているなどの特徴から*Pteroma pendula*あるいはこの近縁種であると同定した。2008年に本種によって何らかの被害を受けたサゴヤシは、試験圃場の植栽グループによって異なるが、サゴヤシの84（Eグループ）～100％（Oグループ）にまで達した。食害を受けたサゴヤシは、全サゴヤシの83％にまで達した。通常および緩効性いずれの尿素肥料の施用も、ミノガの食害を増加させたが、有意な差ではなかった。また、ミノガによる食害は、トゲの大きいサゴヤシの方がトゲの小さいサゴヤシよりもやや大きかった。2010年において、再び、ミノガの食害が認められたが、2008年ほどには広範に食害されず、トゲの大きいサゴヤシ2本にのみ食害が集中し、2本のサゴヤシ生葉の38.5～40.0％が食害された。現在まで、甚大なミノガによる食害はみられていないが、単一種のプランテーションでは、天敵が少なく、ミノガのように爆発的な個体数の増加がみられる種に対するリスク管理が必要であろう。
キーワード：緩効性尿素肥料, 通常尿素肥料, フィリピン, ミノガ

Introduction

There are few pests for sago palm (*Metroxylon sagu* Rottb.). Kimura (1997), however, reported 15 pest insects and animals for sago palm. Several red palm weevils (*Rhynchophorus ferrugineus, R. bilineatus, R. vulneratus*) (Mitsuhashi and Sato, 1994; Mitsuhashi, 2005), the coconut palm rhinoceros beetle (*Oryctes rhinoceros*) (Kimura, 1997), Bess beetles (Passalidae), and bagworm (Lepidoptera: Psychidae) (Kamarudin et al., 1994) infest sago palm. Bagworm larvae of *Pteroma pendula* Joannis (Robinson et al., 1994) utilized a wide range of palms as host plants (Rhainds et al., 2009; Kamarudin and Wahid, 2010). Kamarudin et al. (1994) reported that *P. pendula* distributed in Southeast Asia attacked sago palm. Sago palm leaves were attacked by *P. pendula*, whose young larvae were transported to remote areas by ballooning, a process in which the females of *P. pendula* are blown after emergence of puparium within the pallium. No report about bagworm attacking sago palm leaves has been found in the Philippines.

In Leyte, Philippines, we converted a paddy rice field to a sago experimental field, planted sago palm seedlings with and without thorns in 30 x 30 m field in 2005, and managed sago palms using different types of urea fertilizers (Okazaki and Kimura, 2005; Kimura and Okazaki, 2006a, b; Kimura and Okazaki, 2007; Kimura and Okazaki, 2008; Kimura et al., 2008; Lina et al., 2008; Lina et al., 2009). In December 2007, bagworms were first found in the field where they had infested the young sago palms. Central mountainous areas (Mt. Lobi and Mt. Lumas) divide Leyte Island into two areas of palm distribution: sago palm for the eastern part of Leyte, and buli palm (*Corypha elata*) for the western part (Okazaki and Toyota, 2003; Quevedo et al., 2005). Sago palm seedlings were introduced into western Leyte from eastern Leyte (Brauen) to this area (Pangasugan). This means that sago palms are newcomers to this area. The damage caused by bagworm infestation was not particularly serious until May of 2008. However, almost all sago leaves had been attacked in a bagworm outbreak by July 2008 and, again, in August 2010.

The objectives of this study were to identify bagworm and evaluate the infestation of sago palms by bagworm in Pangasugan, Leyte, Philippines.

Materials and Methods

1. Study site

The sago experimental field was established at

Pangasugan (10º 45'10.7 N, 124º 47'23.6 E), Leyte, Philippines, in 2005. The soil of the field is Eutropept (Lina et al., 2008). A total of 109 sago palms (64 mothers and 45 suckers), 100 of the non-spiny type and 9 of the spiny type, were planted at random in the field. The sago experimental field was subdivided into 6 rows: A, B, O, C, D, and E, from east to west of the experimental field. The experimental plot was 2 x 4 m with different urea fertilizer applications in 2005. In the present situation, 2 plots were compiled to make one plot according to the growth of sago palms. The non-spiny and spiny sago palms were introduced into the experimental field by the end of 2005 by transplanting again to replace dead seedlings. Sago palm seedlings with a mean palm height of 0.66 cm in 2005 were planted in the field (Kimura and Okazaki, 2006a).

2. Bagworm

Bagworm larvae, which had been recorded in early December 2007, gradually increased, resulting in many and serious infestations on the sago palm leaflets. On 21 July, 2008, bagworm samples and their cases were collected and stocked in paper bags. Three months later, two adult male bagworms were collected. The wing specimen was made for identification (Komai et al., 2011). The head and thorax of the adult were treated with a 0.1 % potassium hydroxide solution for several minutes to obtain a precise identification.

3. Sago palm and its management

Applications of a nitrogen fertilizer with two types of urea (normal and slow-release) were performed with the amounts of 0, 50, and 100 kg ha^{-1} in July 2007. The slow-release urea fertilizers used in this study were Meister 40 (M 40) and Meister 70 (M 70) (Asahikasei; the nitrogen content was 40 % for both fertilizers). Meister 40 and Meister 70 are both polymer-coated urea fertilizers in which the release of nitrogen is gradual; this is a type of fertilizer specially designed for the tropics. Meister 40 and Meister 70 are expected to release 80 % of their nitrogen within 400 days and 700 days at 20 °C, respectively (Lina et al., 2008). The experimental plots were Control (without fertilizer), U-50 (urea application of 50 kg ha^{-1}), U-100 (urea application of 100 kg ha^{-1}), M40-50 (Meister 40 application of 50 kg ha^{-1}), M40-100 (Meister 40 application of 100 kg ha^{-1}), M70-50 (Meister 70 application of 50 kg ha^{-1}), and M70-100 (Meister 70 application of 100 kg ha^{-1}) (Lina et al., 2010).

The mean palm height of the mother sago palms in 2008 varied from 3.72 to 5.19 m, and the number of leaves of the mother palms ranged from 10 to 20, with a mean value of 16. Meanwhile, the mean palm height of the mother sago palms in 2010 varied from 4.5 to 9.4 m, and the number of leaves of the mother sago palms, from 11 to 17.

4. Damage determination of infested sago leaves

The number of damaged sago leaves of mother palms and suckers and degree of damage on them were determined by the naked eye in 2008 and 2010: none (0 % of leaflets), slight (0-10 %), moderate (10-20 %), and severe (more than 20 %) (Kimura and Okazaki, 2008; Okazaki et al., 2009; Okazaki, 2011).

5. Nitrogen concentrations in sago leaves

Twenty g of sago leaflet samples was taken from the fourth leaf of three three-year-old sago palms after transplanting. They were dried in a ventilated oven at 70 °C and ground in a mill (Retsch MM 301). The nitrogen concentration in sago leaves was determined with the dry combustion method (Yanaco MT-700) to elucidate the infestation of sago palm by bagworm because a high concentration of nitrogen in plants seemed to induce heavy attacks by pest insects.

Results and Discussion

1. Identification of bagworm

The bagworm venation in fore and hind wings is shown in Fig. 1. The costal, subcostal, radius, medial, cubitus, and anal veins were found in the forewing (Okazaki and Kimura, 2010). The medial veins consisted of "M1" to "M3" wing vein. The bagworm was identified as *P. pendula* (Robinson et al., 1994) and related species of *P. pendula* due to having 11 forewing veins, an M1 wing vein, seven

Fig. 1. Fore and hindwing of *Pterama pendula* Joannis

wing veins in the hind wing, and a closed discal cell. However, there were dissimilarities in the wing veins of the same species that matched the characteristics described by Kamarudin et al. (1994).

2. Infested damages on sago leaves

Infestation of sago leaves by bagworm in 2008 was found throughout the experimental field (Fig. 2). The infestation was more serious in the central area (rows B, O, and C) than in the fringe (rows D and E) of the experimental field in Pangasugan. The mean number of living leaves on one sago palm was 14.4 to 17.5 from row A to E. The sago palms infested by bagworm reached 83 % of the total in 2008 (Fig. 3), which corresponded to 64 (row E) to 100 % (row O) of total living leaves of one sago palm. In 2010, infested sago leaves, however, were found in only one section (row E) of the experimental sago palm field (Okazaki, 2011). The spiny sago palms in the E1 plot had 6 and 5 infested living leaves, which corresponded to 38.5 to 40.0 % of the total living leaves of two sago palms.

Lina et al. (2009) reported that the nitrogen concentration in living leaves of sago palm gradually decreased (from 170 to 120 mg kg^{-1} DW) after leaf development. Nevertheless, the infestation of sago leaves by bagworm did not concentrate on newly developed leaves but, rather, on fully developed living leaves. No significant differences in the mean mother palm height and number of living leaves of mother sago palms among the plots with 0, 50, and 100 kg N ha^{-1} of different types of urea fertilizer application were observed (Fig. 4). Table 1 and Fig. 5 show the degree of infestation and percentages of infestation of

Fig. 2. Infestation of sago leaves by bagworm

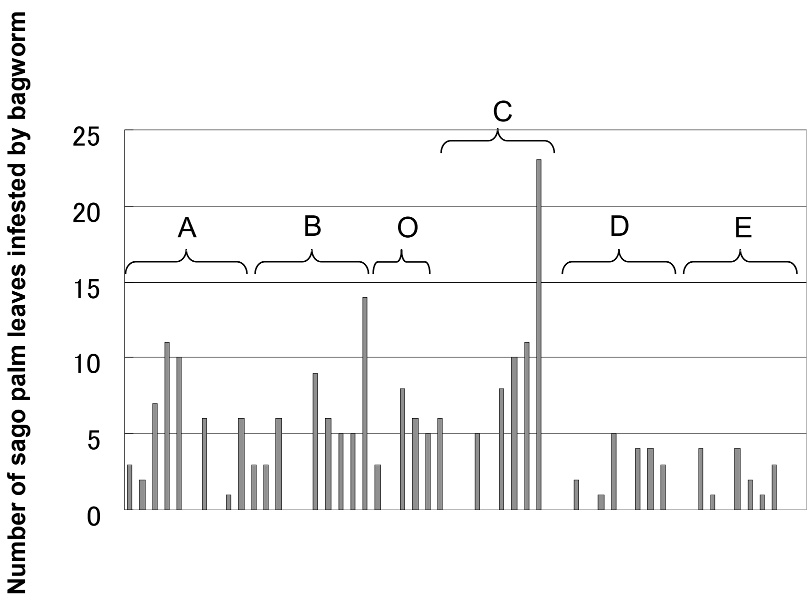

Fig. 3. Number of sago palm leaves infested by bagworm
A, B, O, C, D, and E: Rows from east to west of the experimental field

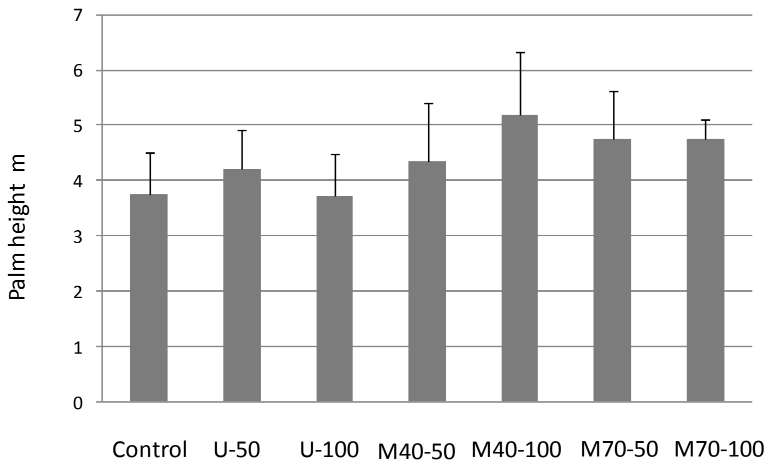

Fig. 4. Effect of urea application on non-spiny mother palm height
Control: Without fertilizer application
U-50: Common urea fertilizer application, 50 kg ha^{-1} N
U-100: Common urea fertilizer application, 100 kg ha^{-1} N
M40-50: Meister 40 application, 50 kg ha^{-1} N
M40-100: Meister 40 application, 100 kg ha^{-1} N
M70-50: Meister 70 application, 50 kg ha^{-1} N
M70-100: Meister 70 application, 100 kg ha^{-1} N
Bar: Standard deviation

the mother palms of the total. In 2008, 83 % of mother palms were infested by bagworm from a slight to a severe extent. Of all sago palms, the percentages of infestation for the categories of none, slight, moderate, and severe infestation were 16.5, 34.9, 10.1, and 38.5 %, respectively.

The increased nitrogen concentration in sago leaves (18.7 mg N g^{-1} DW for Control, 21.5 mg N g^{-1} DW for U-50, and 18.4 mg N g^{-1} DW for U-100) resulted in infestation of sago leaves by bagworm. Bagworms obtain the materials for case-making from living leaves; therefore, the damage caused by *P. pendula*, compared to that by other lepidopterous insects, was serious because of the direct reduction of leaves

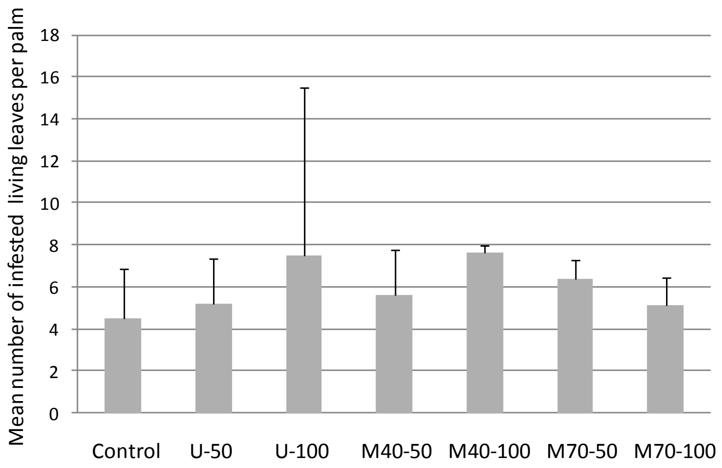

Fig. 5. Mean number of leaves infested by bagworm in the plots of the experimental field in 2008
Control: Without fertilizer application
U-50: Common urea fertilizer application, 50 kg ha^{-1} N
U-100: Common urea fertilizer application, 100 kg ha^{-1} N
M40-50: Meister 40 application, 50 kg ha^{-1} N
M40-100: Meister 40 application, 100 kg ha^{-1} N
M70-50: Meister 70 application, 50 kg ha^{-1} N
M70-100: Meister 70 application, 100 kg ha^{-1} N
Bar: Standard deviation

Table 1. Frequency of different degrees of infested sago palms

Group	A	B	O	C	D	E	Total
None	3	3	0	2	2	8	18
Slight	4	10	2	4	8	10	38
Moderate	3	0	2	2	2	2	11
Severe	10	10	8	9	3	2	42
S+M+S	17	20	12	15	13	14	91
Total	20	23	12	17	15	22	109
Infested (%)	(85)	(87)	(100)	(88)	(87)	(64)	(83)

S + M + S: Slight + Moderate + Severe

undergoing photosynthesis. A monoculture plantation experiences the same problems from pests because of the limited plant species, paucity of natural enemies, and outbreak of bagworms.

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