Reproductive Strategy and Occurrence of Gametophytes of Thai Laver Porphyra vietnamensis Tanaka et Pham-Hoang Ho (Bangiales, Rhodophyta) from Songkhla Province

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Abstract
Reproductive strategy and occurrence of gametophyte phase of Thai laver Porphyra vietnamensis Tanaka et Pham-Hoang Ho were investigated to provide further information for aquaculture. The study was weekly evaluated in two localities of rocky dike; Leam Son-on and Ban Pak Bang Sakhom in Songkhla province during October 1999 to March 2000. Gametophytes, 1.48 (± 0.18) cm in length and 0.42 (± 0.05) cm in width, were visually appeared in early December on the upper level of the dike of both stations. The mature thalli were linear, broad linear or lanceolate, 4.49 (± 0.58) cm in length and 0.75 (± 0.18) cm in width. Spermatangia and zygotosporangia were generally observed from the same plant in early January with size of 10.78 (± 1.68) cm in length and 1.40 (± 0.11) cm in width. Most of them were linear, broad linear or lanceolate in shape. Spermatangial division was 64 (a/4, b/4, c/4) and 32 (a/2, b/4, c/4). While, zygotosporangia division was 8(a/2, b/2, c/2). Biomass was increased to 5.79 and 5.77 g wet weight /100 cm² at Leam Son-on and Ban Pak Bang Sakhom respectively. Archeosporangia were observed in small thalli, 1-3.8 cm in length and 1.1-1.5 cm in width, in late March. The occurrence of gametophytic phase of P. vietnamensis from the two sampling stations was similar. The new populations could be observed at both stations during the sampling time.

Key words: Porphyra vietnamensis, Thai laver, Bangiales, reproductive strategy

Introduction
Thai laver, Porphyra vietnamensis, is annually found growing on rocks at the upper tidal zone in Songkhla, Pattani and Narathiwat, the southern peninsular of Thailand from November to February (Brohmanonda and Sahavatcharin, 1968; Lewmanomont and Chittpolkusol, 1998). The blade is 8-15 cm long and 2.5-4.5 cm broad with elongate or oval shape (Lewmanomont and Ogawa, 1995). On account of the economical potential of P. vietnamensis in Thailand, an effort is performed to gather more information focusing on the local species. There are few reports on reproduction and occurrence of P. vietnamensis population. This study was conducted to demonstrate the suitable time for harvest and to understand reproductive structure and occurrences of P. vietnamensis in southern Thailand.

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MATERIALS AND METHODS

Field sites

Two locations, Leam Son-on (07°13’ 795”N, 100°34’983”E) and Ban Pak Bang Sakom (06°57’ 105”N, 100°49’385”E) in Songkhla Province, Peninsular Thailand were selected for this study because of their high abundance (Figure 1). Both stations have sloping rocky dike situated near the end of river mouth of Songkhla Lake and Thepha River of Songkhla. *P. vietnamensis* attached and grew on the smooth surface of the rocks.

Sampling program

Field sampling was weekly conducted from October 1999 to March 2000. Each station, samples were collected by hand picking during low tides at three sub-station. Water temperature and salinity were recorded during sampling. The blades were taken by 10×10 cm² quadrat, three replications each. They were placed in labeled plastic bags and brought back to laboratory in a cool and dark box. Samples were cleaned, kept out of contaminations and weighed. Complete blades of each sub-station were selected for herbarium sheets and preserved in 5% buffer formaldehyde solution. Thirty specimens of each sub-station were measured and microscopic observed on reproductive cell forming. Morphological reproductive characteristics of the blade of *P. vietnamensis* were checked and compared with the description reported by Tanaka and Ho (1962), Lewmanomont and Ogawa (1978).

![Map showing collection sites](image)

**Figure 1** Collection sites of *Porphyra vietnamensis* at Leam Son-On and Ban Pak Bang Sakom, Songkhla, Thailand.

RESULTS

Occurrence and reproductive strategy

*P. vietnamensis* blades could be observed from December 5, 1999 to March 19, 2000 at Leam Son-on and from December 11, 1999 to March 13, 2000 at Ban Pak Bang Sakom. Blades occurred on the rocks as the rocky dikes in upper-tidal zone of surf-exposed habitats in both stations (Figure 2). Blades were flat, slimy texture and reddish brown in color. The blades mostly grew as a single blade, which some were found clustered. Some blades were branched, and linear-lanceolate in shape before the mature stage.

The surface water temperatures at both stations varied from 26 - 31°C. The lowest range was in December (ca. 27°C) and the highest in March (ca. 31°C). Salinity levels were also similar at both stations and varied from 18-36 ppt.

Reproductive structure and occurrence of the blades at Leam Son-on is shown in Figure 3. During the early seasons of early December, lanceolate blades were observed with an average size of 1.73 (±0.49) cm in length and 0.43 (±0.13) cm in width. Two weeks later, mature blades of 6.36 (±2.13) cm in length and 0.95 (±0.35) cm in width were observed. Spermatangia and carposporangia were estimated about 87 % at marginal blades in mid December. The maximum population of mature blades varied 14.2 cm in length and 1.3 cm in width in late December. Zygotosporangia were first observed at that time and maturation of blade was complete. The blades became gradually irregular and later, broad or oval in early January. However, maturation of blade decreased to 74% in mid January due to new blade appearance among the old population. The mature blades showed second peak of blade size with 10.88 (±3.22) cm long and 1.50 (±0.58) wide in early February. Spermatangia, carpogonia and

![Figure 2](image-url) Habitat and growing of *Porphyra vietnamensis* blade at two localities. A. and B. Growing blades at Leam Son-on, C. and D. Growing blades at Ban Pak Bang Sakom.
zygotosporangia showed similar to the old one in early February. Finally, small oval form of blades was appeared at the highest tidal level in early of March. Archeosporangia were observed in small thalli, 1.71 ($\pm$0.07) cm in length and 1.05 ($\pm$0.06) cm in width in mid March. All blades were disappeared in late March. Reproductive structure and occurrence of blades at Ban Pak Bang Sakom is shown in Figure 4. The average size of 1.73 ($\pm$0.50) cm long and 0.35 ($\pm$ 0.13) cm wide blades were observed in early December. In late December, 77% of the collected blades have spermatangia and carpogonia on blade margin, and the largest size

![Diagram](image_url)

**Figure 3** Percentage of mature blade, type of gametangia and blade size of *Porphyra vietnamensis* at Leam Son-on, Songkhla, Thailand (n=30).

![Diagram](image_url)

**Figure 4** Percentage of mature blade, type of gametangia and blade size of *Porphyra vietnamensis* at Ban Pak Bang Sakom, Songkhla, Thailand (n=30).
of blade was 7.65 (±1.87) cm long and 0.52 (±0.18) cm wide. In early January, the blade size became shorter, while spermatangia, carpogonia and zygotosporangia were found in patches on the blade margin. Mixed populations of young and old blades were observed in late January. In mid February, the maximum blade size of 8.40 (±0.2.20) cm long and 1.53 (±0.65) cm wide was observed, then it became shorter and decayed.

**Microscopic structure**

Marginal denticulations of the blade have 1-3 cells (Figure 5, A) in each denticulation. The diameter of vegetative cells were 15-17.5 µm. The thickness of blade in early mature phase was moderately thick and varied between 45-47 µm at the central part. The cells at the basal part of blade were 14-18 µm in length with elongate rhizoidal cell (Figure 5, B and C). Formation of reproductive cells on the edges of the upper regions of blade occurred in patches (Figure 5, D). Sporangium was divided into 32(a/2, b/4, c/4) or 64(a/4, b/4, c4) and in the late stage of blade (Figure 5, E and F). Zygotosporangia were observed on the inner side of spermatangia along the blade margin (Figure 4, G). Zygotosporangial patches were also found the inner blade and the zygotosporangium divided into 8 (a/2, b/2, c/2) (Figure 5, G and H). Some of archeospore (following the terminology of Magne 1991) germlings could be observed on marginal part of small blade, 1-3.8 cm in length and 0.4-2.2 cm in width (Figure 5, L). Archeosporangia were slightly rounded with 11-15 µm in diameter and mixed with spermatangia, carpogonia and zygotosporangia (Figure 5, J and K).

**External morphology and density**

In early stage, linear lanceolate and lanceolate blades occurred in early December. Ovate shape blades were observed at late phase of occurrence in early January, and small number of elongate, ovate and round shape of blades was appeared in this season. Most of the blades were solitary while some blades growing on rocks in colonies. Some blades were ripped vertically from the tips or the sides. Weekly changes of the typical forms of blade of this species at Leam Son-on and Ban Pak Bang Sakom are shown in Figure 6 and Figure 7, respectively. In early mature stage, the blade showed typical lanceolate form (Figure 6, C and I and Figure 7, C and F). Branched bladelets were frequency found on the blades after spermatangia were released (Figure 6, D and Figure 7, F). The color of blade was reddish brown, dark brown or yellowish brown. The form of blades gradually became irregular and later the blades became broad, ovate, V-shaped or cordate.

Biomass at two sites showed similar patterns as shown in Figure 8. Early stage of occurrence had 0.06 g and 0.12 g wet weight /100 cm² g at Leam Son-on and Ban Pak Bang Sakom, respectively. The biomass increased dramatically and firstly peaked of 5.79 g and 5.77 g wet weight /100 cm² in early January at Leam Son-on and Ban Pak Bang Sakom, respectively before decreased in mid and late January. However, the biomass was reached their highest of 10.18 g and 9.26 g wet weight /100 cm² on February in each station, respectively, before decreased and disappeared in March.

**DISCUSSION**

The occurrence of gametophyte phase of *P. vietnamensis* in Songkhla, Thailand was displayed in the same time as in previous studies by Themmedth (1960), Brohmanonda and Sahavatcharin (1968) and Lewmanomont and Ogawa (1978). Although in this study, some differences existed because the occurrence of the blades was late when compared with the reports of Themmedth (1960) and Lewmanomont and Ogawa (1978) that starts from November.

The occurrence of the blades from present study was likely to be the results of lowest temperature and salinity. Data of the highest and
the lowest temperature and rainfall of Songkhla Province from Meteorology Division (2000) of Thailand supported that at the time of blade appearance there was a drop in temperature and heavily raining at the same time. However, the occurrence time between two sampling locations, Leam Son-on and Ban Pak Bang Sakom, showed slight difference in terms of blade appearance. Characteristics of *P. vietnamensis* closely resemble to *P. tanegashimensis* (Shimura 1974), but the latter has well developed bladelets. It is also similar to *P. marcosii* (Cordero 1976) but differ in blade thickness. There were some differences of blade color and thickness in those of three species. Those of mature blades of *P. vietnamensis* were thickness (in the range of 40-

**Figure 5** Structures of *Porphyra vietnamensis*. A. Dentate margin, B. Rhizoidal cells on surface view, C. Rhizoidal cells on transverse section view, D. Patches of spermatangia and zygotosporangia, E. Spermatangia on surface view, F. Spermatangia on transverse section view, G. and H. Zygotosporangia on surface view, I. Zygotosporangia on on transverse section view, J. Germlings of archeospore inside and on the blade margin, K. Archeosporangia on surface view, L. Archeosporangia on transverse section view. (scale bars, 20 mm).
60 µm), while *P. tanegashimensis* and *P. marcosii* were thin (less than 40 µm). In addition, color slightly differed and varied from light purple to yellowish brown. However, those characters could vary depending on age of plant, habitat and duration of time. (Shimizu 1983). It is necessary that detailed studies on shapes of blade before or at early maturation stage, position and division of gametangia and DNA sequences must be carried out to clarify overlapping of species.

The specimens from Songkhla, Thailand reported in this study, were agreed well with the original description based on blade shape, blade size, blade margin, basal part, sexuality, spermatangial and zygotosporangial cell division formula. The blades were appeared linear-
lanceolate shape with the size of 4-14×0.5-2.5 cm with serrated margin. Bladelets of some thalli were observed. Basal part composed of rhizoidal filament. Division of male gametangia was 64 \((a/4, b/4, c/4)\) and division of female gametangia was \(8(a/2, b/2, c/2)\). Curiously, new pattern of spermatangial division of \(32(a/2, b/4, c/4)\) was noticed in \(P. vietnamensis\). This was similar to Notoya and Nagaura (1998) who suggested that gametangial divisions of \(P. lacerata\) can be observed more than one type.

After maturation time of \(P. vietnamensis\), spermatangia, carposporangia and zygotosporangia were observed throughout the appearance time. It is similar to the reported data on \(P. spiralis\) (Kapraun and Lemus 1987) which spermatangia and carposporangia can be found. In \(P. vietnamensis\), sperametangia formed along the edge of blade margin and carpospoangia existed adjacent in the inner side whereas in \(P. spiralis\), in mixed marginal patches on the blades. However, production of reproductive cell in the both species was different from \(P. tanegashimensis\) that produced sexual reproductive cells at early phase and produced asexual reproductive cells later.

The phenomena of new population occurring among the existing old population that occurred in late January is similar to growth pattern of \(P. linearis\). Majority of the population was established in the supratidal zone from October to March and a few new blades appeared in April to August (Bird 1973). However, the type of reproductive cells in mature blades clearly indicated that only sexual reproductive cells were produced at a time. Archeosporangia were not observed at the time that the new blades occurred. It could be assumed that the new populations come from conchospore germlings. Furthermore, the

**Figure 8** Density of \(P. vietnamensis\) blade at Leam Son-on and Ban Pak Bang Sakom, Songkhla, Thailand.
archeosporangia were observed on late season in March and only at Leam Son-on Station, water temperature increased to 31°C. The phenomena of archeospore production in the nature was similar to other temperate species e.g. *P. okamurae* (Tanaka 1952), *P. yezoensis* (Kurogi 1961) and *P. tenera* (Fukuhara 1968), that archeospores in the nature were usually found in autumn at high water temperature. However, new plants from archeospores of *P. vietnamensis* could not be noticed due to small size because of unsuitable conditions season (high temperature and salinity) during late season.

Succession of blade shape of *P. vietnamensis* that was linear-lanceolate in early phase and varied to oval in late phase is similar to variation of blade shapes of *P. tanegashimensis* (Shimura 1974). *P. tanegashimensis* showed linear shape at early time of appearance and became rounded later. Variation of blade shape, blade size, succession of reproductive cells and biomass observed at both stations may be due to similar environmental conditions.

In addition, it seemed to have new populations were observed at both stations. It was possible that suitable condition stimulated production of edolithic conchosporangia, and conchospores released in the same time attached on the rock related to tidal level. Data from blade size and biomass showed that the first population grew denser than the second population at both stations.

**LITERATURE CITED**


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