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Phenology of the Parah tree (*Elateriospermum tapos*) using a GAPS Model

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***Abstract*—**This work investigated the phenology of Parah tree (*Elateriospermum tapos*) using the General Purpose Atmosphere Plant Soil Simulator (GAPS model) to determine the amount of Plant Available Water (PAW) in the soil. We found the correlation between PAW and the timing of budburst and flower burst at Khao Nan National Park, Nakhon Si Thammarat, Thailand. PAW from the GAPS model can be used as an indicator of soil water stress. The low amount of PAW may lead to leaf shedding in Parah trees.

***Keywords*—**Basic GAPS, Parah *(Elateriospermum tapos)*, Phenology, Climate, Nakhon Si Thammarat, Thailand.

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I. Introduction

IN tropical regions, leaf phenology and demography are highly diverse across various tree species [1-2]. Because leaf phenology and demography strongly influence forest productivity and plant-animal interactions, these traits have been investigated in various tropical forests [3-5]. Leaf phenology has been related to abiotic factors, such as the amount of rainfall or water stress [5-6]. In aseasonal tropical rain forests, water stress would not be the main factor affecting leaf phenology [7-8]. Alternatively, irradiance seasonality and the effects of herbivores have been emphasized as the main factors [7, 9]. However, most of these studies have concentrated on leaf phenology at forest community, species and/or individual tree levels.

In aseasonal forests, seasonality in meteorological factors does not regulate the phenology, and the timing of leaf production may depend on the accumulation of carbohydrates in the shoots. Actually, leaf production phenology is not related to any meteorological factors at the population level, and the frequency of leaf emergence (per year) is greater in saplings exposed to more light in a tropical tree, such as *Elateriospermum tapos* [10].

Parah (*Elateriospermum tapos*) is the only plant in the monotypic family native to Thailand, Malaysia, and Sumatra Island. Parah (*Elateriospermum tapos*) is found at Jengka national forest in Malaysia [11], Belalong forest in Brunei [12] and Khao Nan National Park in Thailand. This species is abundant on the very friable, relatively nutrient rich soil of the Sega neat series, with lower soil-water content, at least in the dry period [11].

Leaf phenology has been studied in individuals of a canopy species, *Elateriospermum tapos* (Euphorbiaceae), at various ontogenetic stages in a Malaysian rain forest [13]. The timing of leaf emergence was not synchronized among sapling individuals, and was not correlated with any meteorological factors of the preceding month. The leaf production rate is greater when there is more light, but the leaf shedding rate is not related to the light regime of the saplings. Thus, leaf production is enhanced by the light availability for each individual. Non-synchronous leaf production appears to be important for sapling growth allowing saplings to occupy better-lit space quickly.

This work aims to study the phenology of the Parah tree (*Elateriospermum tapos*), using the General Purpose Atmosphere Plant Soil Simulator model (GAPS model) to determine the amount of Plant Available Water (PAW) in the soil and find some association between PAW and budburst and flower burst at Khao Nan, Nakhon Si Thammarat, Thailand.

II. Materials and Methods

A. Study Site

Khao Nan is located at 8° 22'- 8° 45' N, 99° 37'- 99° 51'E, southern Thailand (Fig. 1). We installed the Davis Vantage Pro II plus wireless weather station (hereafter known as the Davis weather station) at the Parah Forest (latitude 8.86543 N and longitude 99.62230 E) on the 21st November 2006 (Fig. 1).

B. Phenology Data Collection

We selected 30 Parah trees at the Parah park ranger station and marked these 30 Parah trees by placing an individual tag on each tree at a height of 1.30 m.

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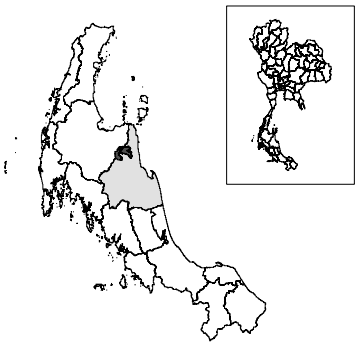
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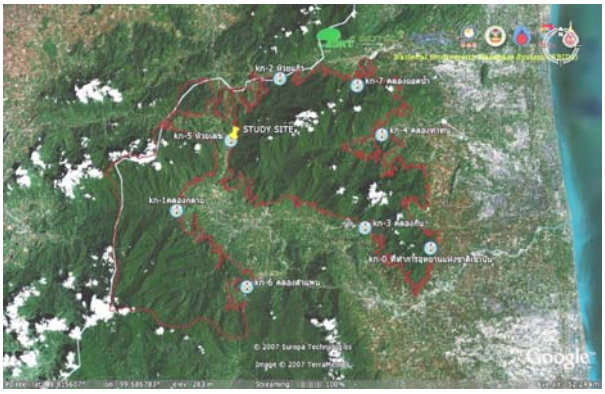
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(a)



(b)

Fig. 1 (a) study area at Khao Nan National Park, Nakhon Si Thammarat province, Thailand, and (b) Parah park ranger station (yellow pin)

We measured the diameter at the base (DAB), the diameter at the breast height (i.e. 130 cm) (DBH), and the tree height. We selected three branches/tree and marked them with green ribbons. We visited selected Parah trees once every two weeks and recorded the timing of budburst and the flowering burst at the top, the middle and the base of Parah trees.

C. GAPS Model

The basic GAPS model was a dynamic, deterministic simulation model of the "soil-plant-atmosphere" system. The GAPS model described water uptake by plants, water and heat flux in the soil, and the climatic impact on these processes [13]. The GAPS model required four types of inputs: climatic inputs, soil inputs, phenology inputs and coordinates of the study site. First, climatic inputs were composed of daily maximum/minimum and current temperature, and the amount of daily rainfall. Second, soil inputs were composed of soil characterization (i.e. layer number, root estimate, root density, depth to top/bottom layer thickness, slope of study site, and horizon texture), and soil particle size. Third, phenology inputs were composed of green-up date, and green-down date. Fourth, coordinates of study sites were composed of Latitude, Longitude and elevation. We collected the soil and atmospheric data by using GLOBE protocols [14].

D. Climatic and Soil Data

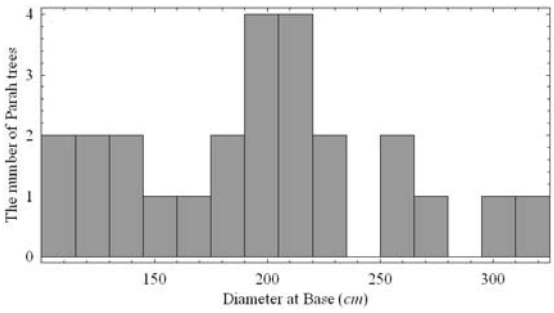
Climatic data were collected using the Davis weather station. Climatic factors were composed of the amount of daily rainfall, max/min temperature, relative humidity, solar radiation, UV, wind speed, wind direction and soil water suction at 10, 30, 60, and 90 cm depths. Climatic factors at Parah forest were collected from November 2006 to June 2007. The soil was sampled from study sites at four soil depths: 7, 20, 58, and 90 cm using a soil auger. Additional soil samples were taken at four soil levels and sent to process at the Land Development Department to determine soil field capacity and permanent wilting points.

E. Data Visualization and Analysis

PAW was the water considered available for plant uptake and calculated as the mass or volume of water between the field capacity water content and the permanent wilting point water content of the volume of soil in the root zone of the plant [14]. Computer programming was written for visualizing data and examining the correlation between the PAW from the GAPS model and the percent soil moisture using *Mathematica* version 6. Parametric statistics were used when underlying assumptions were met. Linear regression was used to test for the association between PAW and soil water suction. All significant tests were two-tailed.

III. Results and Discussion

Parah trees had a mean ±SD of DAB of 226.87 ± 91.68 cm, DBH of 138.00 ± 46.13 cm, and tree height of 31.03 ± 9.41 m. The timing of Parah budburst started on the 13th February 2007 and ended on the 24th March 2007 with a budburst duration of 40 days. The mean ± SD of the number of budbursts at Parah forest was 2.25 ± 2.97 branches/day. The maximum number of budbursts/day occurred on the 1st March 2007 with a total of 17 branches/day. The flower burst started on the 15th February 2007 and ended on the 30th March 2007 with a flower burst duration of 44 days. The mean ± SD of the number of flower bursts at the Parah forest was 2.05 ± 2.81 branches/day. The maximum number of flower bursts/day occurred on the 8th March 2007 with a total of 12 branches/day. This indicates that the timing of budbursts occurred 1 week prior to the timing of flower bursts. There were two day time lags between the timing of budbursts and flower bursts of Parah trees at the Parah park ranger station, Khao Nan National Park (Fig. 2. a-c).



(a)

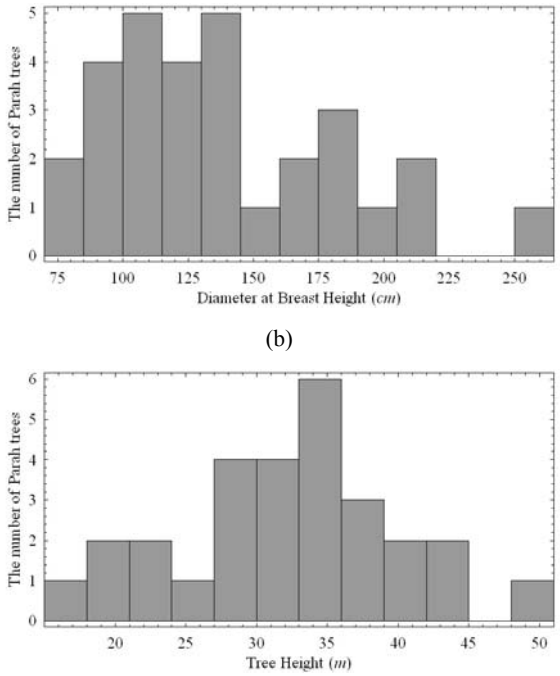


Fig. 2 (a) DAB (cm), (b) DBH (cm), and (c) Tree height of 30 selected Parah trees

PAW from the GAPS model were negatively associated with soil water suction collected from the Davis weather station at all four soil layers (Simple linear regression: first soil layer: $y = 44.162-0.5835x$, $R^2 = 0.018$, $F_{1,205} = 3.807$, $P = 0.052$; second soil layer: $y = 111.578-3.538x$, $R^2 = 0.378$, $F_{1,211} = 134.16$, $P<0.001$; third soil layer: $y = 57.763-0.642x$, $R^2 = 0.026$, $F_{1,221} = 5.849$, $P = 0.01$; four soil layer: $y = 19.490-0.278$, $R^2 = 0.029$, $F_{1,217} = 6.548$, $P = 0.01$, Fig. 3 a-d). Soil water suction showed the energy status of soil water. High soil water suction meant less soil moisture. Our results showed a negative relationship between PAW and soil water suction. This indicates that there was less soil moisture (low PAW and high soil water suction) and might be a drought period. PAW from the GAPS model could be used to predict a drought period.

The mean ±SD of climatic factors at the Parah forest from November 2006 to June 2007 was 24.0 ± 3.14 °C with a relative humidity of 90.8 ± 10.61 %, and a daily rainfall of 4.68 ± 10.64 mm. During budburst, there was almost no rainfall (Fig. 4 a-f). This may suggest that Parah trees require some drought period as an indicative cue for budbursts. This drought stress signal for leaf shedding, budburst, and flower burst have been shown in many crop species including wheat, and sorghum [15-16].

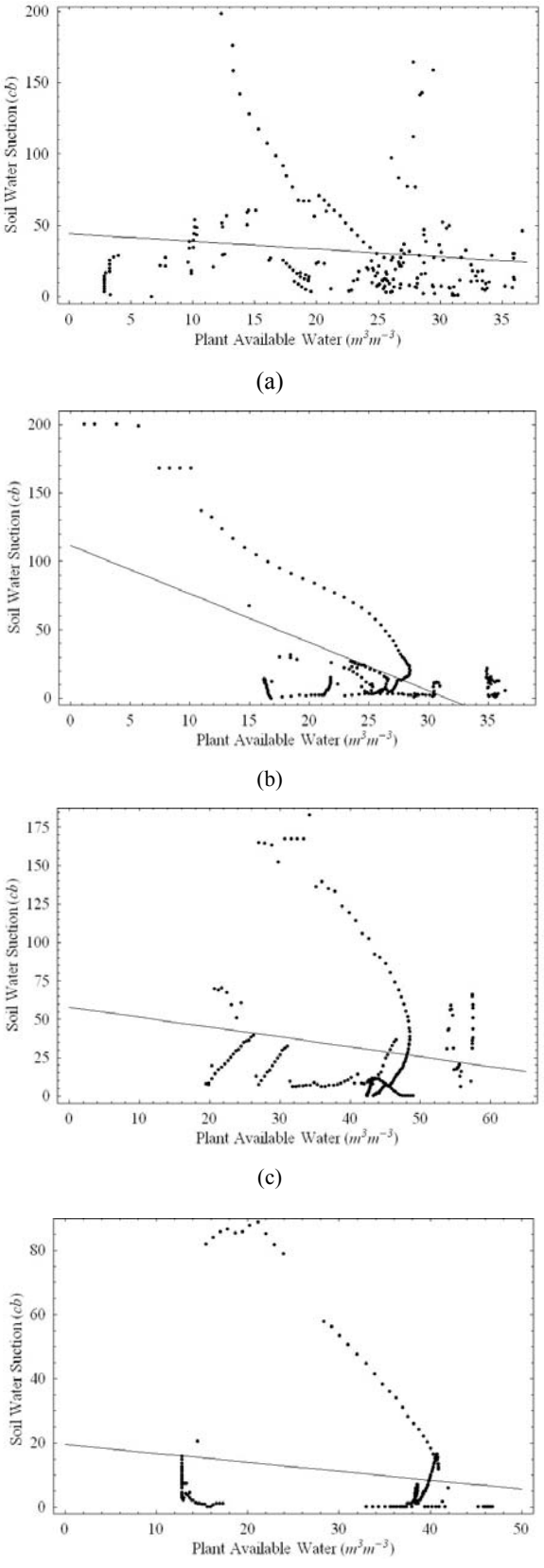


Fig. 3 Regression between PAW and soil water suction. (a) first soil layer, (b) second soil layer, (c) third soil layer, and (d) fourth soil layer

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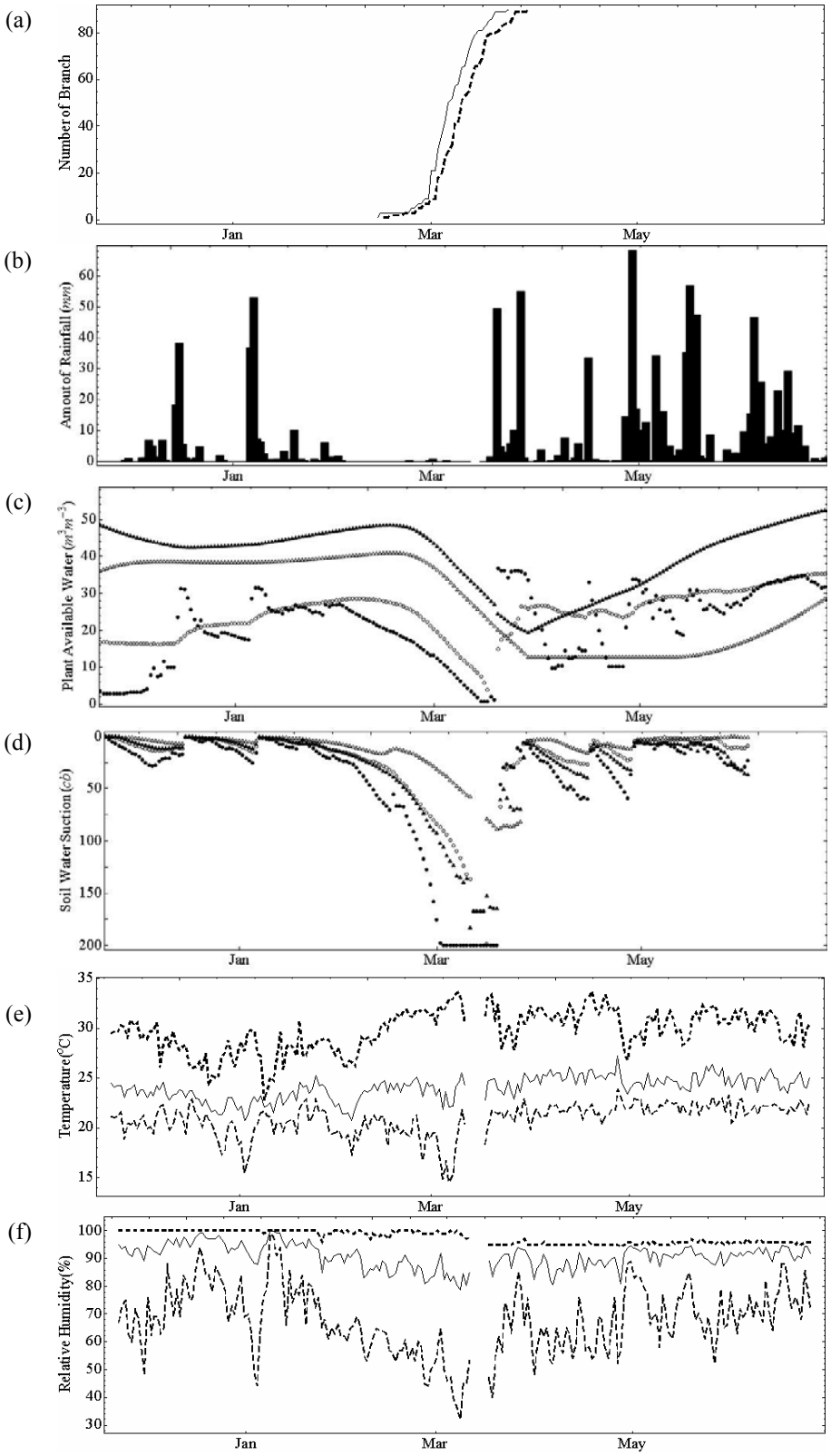


Fig. 4 Timing of Budbursts and climatic factors. (a) the accumulative number of budbursts (—) and flower bursts (----), (b) the amount of daily rainfall (mm), (c) PAW at four soil levels (● 1st, ○ 2nd, Δ 3rd, ▲4th soil level), (d) Soil water suction at four soil levels (● 1st, ○ 2nd, Δ 3rd, ▲4th soil level), (e) Maximum (– – – –), Mean (—), and Minimum temperature (----), and (f) Maximum (– – – –), Mean (—), and Minimum relative humidity (----)

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Our study observed only mature Parah trees and found that tall mature Parah trees showed a clear synchronous budburst and flower burst pattern in March-April. Osada et al. [10] also found a similar pattern of leaf shedding with tall mature Parah trees showing a clear synchronous annual leaf fall pattern. Our results support Osada et al. [1]'s findings that mature Parah trees produce flowers simultaneously with new leaves after shedding their leaves. This suggests that the need to synchronize flowering might be the primary determinant of leaf production phenology in mature individuals.

Our results showed that leaf shedding started from the top of the crown and moved down to the tree base. Tall trees have large crowns and the light microenvironments vary widely within the crowns [17-18]. Such variation in light microenvironment might be expected to affect the shoot growth patterns and leaf phenology within the crowns. For efficient crown development, the enhancements of shoot extension and associated leaf production are more important for sunlit parts that for shaded parts of the crowns [19-21]. Therefore, leaf production rate was greater in the upper than in the lower crowns for Parah trees [1].

Our results did not support previous findings [5, 6] that phenology patterns would be possible only in seasonal forests. Parah trees are situated in a aseasonal forest. These Parah trees showed strong phenology patterns such as leaf shedding, budburst and flower burst. This phenology pattern mainly is influenced by severe drought. Water stress in dry seasons strongly regulates the leaf phenology in tropical dry forests, with most of the leaves being sheded during the dry season. We found that the timing of budburst and flowering of Parah trees was negatively associated with the amount of rainfall, PAW, maximum temperature and the percentage of minimum relative humidity.

Our results showed negative association between PAW and soil water suction in all four soil layers. This suggests that the GAPS model can determine the amount of soil water content, even though it might be less accurate than a sensor measurement. The GAPS model can be downloaded from the GLOBE website. The GAPS model is suitable for researchers, teachers and students to find soil water content, PAW, potential evaporation, potential transpiration, potential evapotranspiration, actual transpiration, daily precipitation, actual evaporation, and etc. [14].

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