



The Effect of Microclimate Factors to Floral Traits on Flowering Season in Teak (*Tectona grandis*) Seed Plantations, Thailand

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ABSTRACT

Variation in environmental factors at the individual seed plantation is an important for site specialization on management and improvement to have been sustainable yields. This study was conducted at the main five teak seed orchards during the peak blooming season in Thailand to investigate the relationships between floral traits (pollen grain and nectar) and environmental factors such as photosynthetic active relation (PAR), leaf area index (LAI), temperature and relative humidity. Among microclimate factors of each site, only PAR, LAI and temperature were significantly different, showing differences among sites variation in light intensity and sunlight at occurring of individual condition. It was found that only temperature is a factor influenced, which implies that the quantity and quality of nectar depend on air temperature and basking duration of time in those flowering of trees. The results showed that the relationship significantly differed between in floral nectar and environmental variables in each period for pollination which may be related to some major pollinator behavior or limited their activities.

KEYWORDS: teak, seed plantation, microclimate, factors, floral traits

INTRODUCTION

Successful pollination is critical for fruit setting of those plants and insect visitors play an important role. The effective of pollination depends on the reproductive system of the plant fitness, environmental factors and the availability of pollinators. Thus, it is important to understand the factors affecting the pollination processes. Many studies reported that some environment factors may be related to reproductive success of plants [9, 11, 15, 16]. High or extreme temperature on sunny days can cause drying of stigma surface [24], and also seed abortion and reduced fruit setting [5, 22]. However, habitat types and some environmental factors may also affect the diversity and activities of pollinators that visit flowers. Floral traits can also cause important factor that differential the foraging niches among insect visitors [8, 11], which are linked to the reproductive success of plants.

Teak (*Tectona grandis* L.f.) is one of the famous timber species of the Southeast Asia. Many countries of the world have been established as plantations [6, 12, 13, 14, 20]. In Thailand, teak plantations have been expanding rapidly on a small or large scale. But the planting trees are still limited, due mostly to an insufficiency for quantity and quality of seed. Effective production of large quantities of high quality seed is necessary to overcome the difficulty. Many locations generally have reported low fruit setting of teak [10, 18, 21].

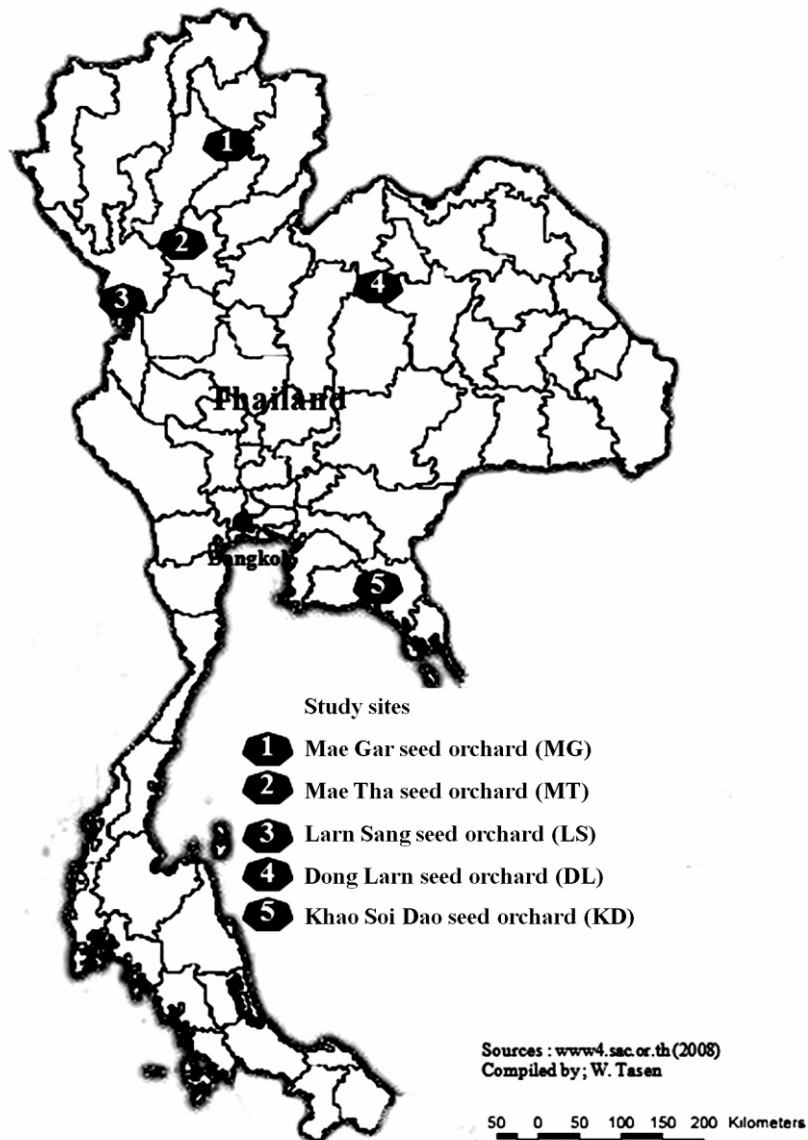
However, the causes of low fruit set of teak in each seed plantation are still unclear. The objective of this study is to investigate some missing information by reporting on the variations in floral traits and microclimates and to determine any regional differences. This study reports on the relationships between floral trait and environmental variables on blooming season of teak in different sites. The variation in microclimate factors that affect to floral trait variables and insect behaviors for pollination success of teak in each area.

MATERIALS AND METHODS

The study areas are located in five clonal seed orchards of teak, Thailand (Fig. 1): Mae Gar Silvicultural Research

Station (19° 10' N, 99° 55' E, 340 m elevation), Phayao province; Mae Tha Silvicultural Research Station (18° 11' N, 99° 34' E, 336 m elevation), Lampang province; Larn Sang Silvicultural Research Station (16° 48' N, 99° 2' E, 373 m elevation), Tak province; Dong Larn Silvicultural Research Station (16° 48' N, 101° 58' E, 363 m elevation), Khon Kaen province; and Khao Soi Dao Silvicultural Research Station (12° 58' N, 96° 17' E, 250 m elevation), Chantaburi province. The orchards are mainly managed as teak seed plantations, grown at 12x12 m spacing and 31-34 yr-old of trees.

Fig. 1 Map showing the study sites at the five teak seed orchards in Thailand



Observations were conducted during the peak blooming season i.e. from 20 July to 20 August 2008 to investigate possible relationships between visitation frequencies and floral traits of each site, several variables related to number of pollen grains and floral nectaries were calculated. At the middle of the flowering season, number of the pollen grain was collected randomly from five trees of each site; flowers were preserved in formaldehyde-acetic acid-ethanol (2:1:1, v/v/v, 50% FAA) solution.

To investigate the quality and quantity of nectar production by individual flower, nectar volumes and concentrations were directly measured at the study site in the period of each hour (09:00 to 15:00). The flowers in each inflorescence were bagged before flower opened between 07:00 to 08:00 on the day. The bags were then removed

for nectar measures at 09:00, which is start point of the peak receptive period. The highest period for teak pollination was from 11:00-13:00 [24]. Nectar volumes were resolved by inserting a 2 μL capillary tube down to the base of each flower. Because of a small amount of nectar produced, several flowers were pooled for measuring fresh nectar concentration by using a hand-held refractometer (Nippon Optical Works, Tokyo, Japan). Nectar samples were collected from teak flowers at Mae Gar seed orchard between 09:00-11:00 (forenoon) and 12:00-14:00 (afternoon) and the amount of glucose and fructose were determined by Waters 626 high performance liquid chromatography (HPLC) (Waters Corp., Milford, MA, USA) with an Aminex HPX-87H column (Bio-Rad, Hercules, Calif., USA) at 65°C, using 5 mmol H_2SO_4 as a mobile phase at a flow rate of 0.6 mL/min. Glucose and fructose were detected based on measurement of the refractive index (Waters 410 Differential Refractometer Detector, Millipore, Milford, MA). Measurements of environmental factors and observation of flower visitors were conducted between 09:00 to 15:00 in the plantation. The PAR (Photosynthetic Active Radiation) and LAI (Leaf Area Index) of each seed orchards were measured using an AccuPAR model LP-80 (Decagon Devices, Inc., USA), which is the photosensors measure PAR in the 400-700 nm wavelength whereas air temperature, relative humidity and wind speed, were measured using a Kestrel 4000 Pocket Weather Tracker (Nielsen-kellerman Kestrel, NK).

We used the proportion of microclimates in each site for the measure of each time-period and sites, and then compared arcsin-transformed data with a one-way ANOVA. All of the data obtained from flowers or trees were averaged for each site, and the variables were first tested for homogeneity of variance (Levene's test) and a normal distribution (Kolmogorov-Smirnov) to meet the requirements of ANOVA. We compared the means and standard errors from calculation for all measurements. SPSS® 13.0 for Windows [23] was used for all statistical analysis.

Relationships between floral nectar and environmental variables were examined by principle correspondence analysis (PCA) using PC-ORD version 5.10 for Windows [17]. We performed data matrices of log-transferred floral nectar and microclimate variables. The biplots graph provided information on floral nectar and environmental variables and pollination time-period, relative to their scores, on the two main axes of the ordination.

RESULTS AND DISCUSSION

Variation in floral traits and microclimates

In the floral morphology of each teak seed orchards, the average number of pollen grains and floral nectar variables were considered in this study. No significant in the pollen grain of the flowers was observed ($F_{1,49} = 1.93, P = 0.122$). The number of pollen grains per anther for each individual sites ranged between $2,094.22 \pm 259.21$ and $3,304.09 \pm 666.36$ (mean \pm SD). Differences of nectar volume per flower between the sites and the periods for pollination from 09:00 to 15:00 did not differ significantly ($F_{1,34} = 2.07, P = 0.110$; $F_{1,34} = 1.34, P = 0.271$, respectively). Floral nectaries of teak located in orange colored tissues around the base of the ovary [24], which the quantity of nectar is related to the volume of the nectar parenchyma [3, 19]. The sugar concentration of nectar did not differ significantly for all sites, while in each period for pollination was significant difference ($F_{1,34} = 187.33, P < 0.001$). This indicated that concentration of nectar depended on the duration of the nectar exudation in the daytime. However, the floral morphology i.e., number of pollen grains and floral nectar in each site did not differ significantly, indicated that the number of pollen grains and nectar did not relate to habitat types. The previous studies clearly demonstrated that the character of teak pollen was medium tricolpate, which pollen size did not differ in diameter of hydrated pollen [24]. Pollen had high viability (92.2%) after anthesis 4 hours and there was no significant difference in pollen germination among trees [25] and different crown directions [4].

Variation of microclimate in each of seed orchards differed significantly in means of PAR ($F_{1,69} = 3.161, P = 0.028$), LAI ($F_{1,69} = 4.085, P = 0.009$) and air temperature ($F_{1,69} = 2.64, P = 0.042$) but not differed in relative humidity ($F_{1,69} = 2.38, P = 0.061$). Only PAR differed significantly ($F_{3,32} = 7.53, P = 0.010$) in each period for pollination (09:00-15:00). The PAR variable on individual of seed orchards ranged between 79.50 ± 51.22 and $1333.70 \pm 161.89 \mu\text{mol m}^{-2} \text{s}^{-1}$. The LAI ranged between 0.81 ± 0.09 and $3.28 \pm 0.34 \mu\text{mol m}^{-2} \text{s}^{-1}$. The temperature was measured between 24.30 ± 1.86 and 32.50 ± 2.31 °C. The relative humidity ranged between 55.10 ± 4.14 and 90.40 ± 6.50 %.

Differences between seed orchards in means PAR, LAI and temperature variables were highest during 11:00 to 13:00 in the day time. Figure 2 showed site-dependent variation in light intensity and sunlight occurring on each time of day at the site. The relationship between floral morphology (floral nectar) and microclimate (PAR, LAI,

temperature and relative humidity) was also expressed in Fig. 3. The temperature affected the sugar concentration and volume of nectar significantly ($F_{2,33} = 24.353, P < 0.001$; $F_{2,33} = 27.024, P < 0.001$, respectively).

The quality sugar of nectar, both of glucose and fructose variables on the forenoon period (09:00-11:00) of flowering was significantly lower than that the quality of nectar in afternoon period (12:00-14:00) ($P = 0.005$ and $P = 0.022$, respectively). The percentage of glucose ranged between 6.92 ± 1.66 and 17.60 ± 1.03 and the fructose ranged between 8.14 ± 1.56 and 20.24 ± 2.95 .

Among microclimate variation of each seed orchard, only PAR, LAI and temperature variables were significantly different showing the differences among sites in light intensity and sunlight. However, individual location had a characteristic temporal pattern, which may be depended on duration and timing of direct insolation periods [9].

The quantity and quality of floral nectar productivity depends on environmental factors, especially temperature. The results showed that the quality of glucose and fructose increased in the afternoon than forenoon, which the sugar concentration of nectar was distinctly high (see Fig. 3a).

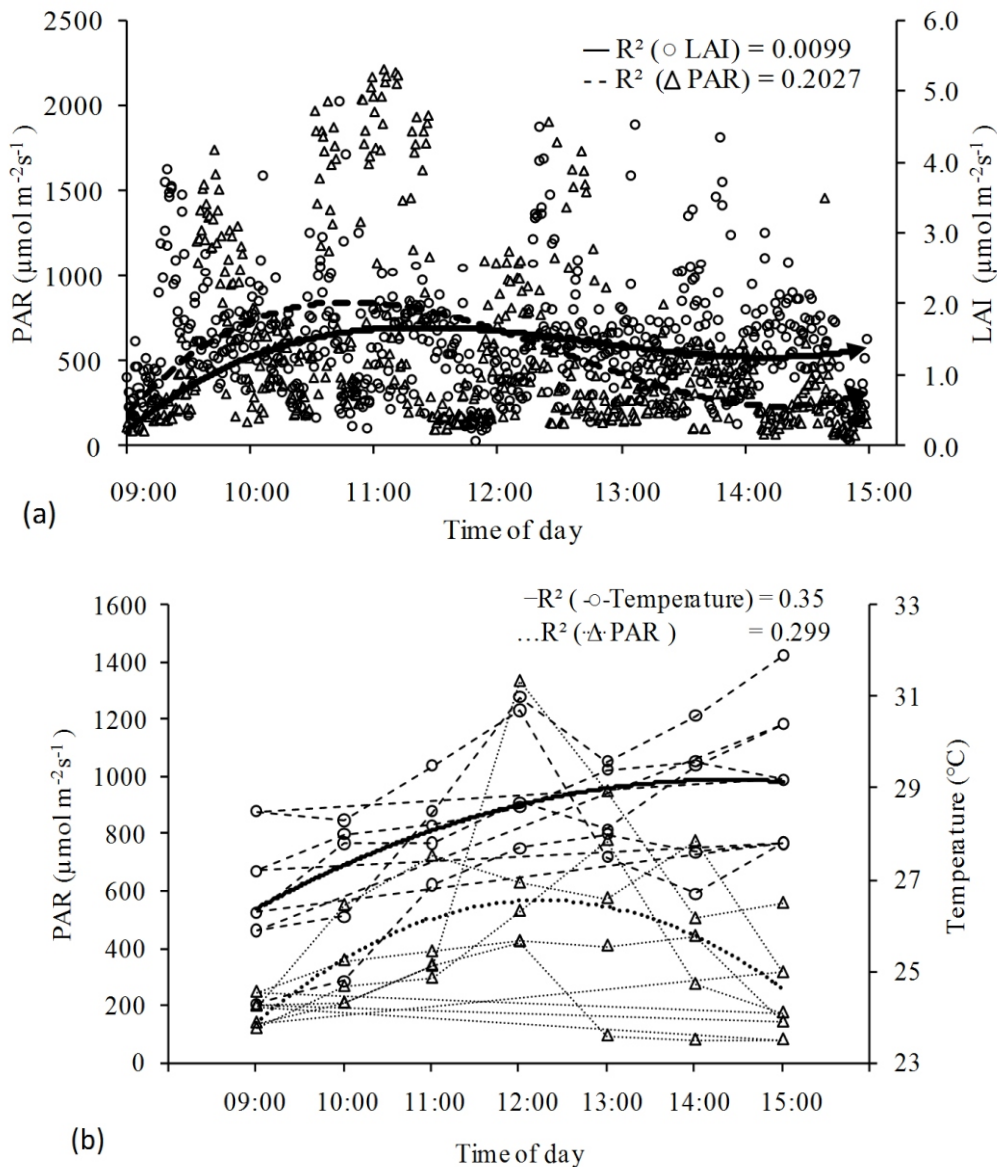


Fig. 2 Variation among studied sites in environmental variables from each period for pollination during 09:00 to 15:00 in teak seed orchards. (a); scatter plots of solar irradiance (PAR) and leaf area index (LAI) variables and (b); relationships between solar irradiance and temperature variables in period for pollination of teak flowers.

This results was also agreed with the report of Alekseyeva and Bureyko [1] found that the temperature have influenced to excretion of nectar.

Relationship between floral nectar and microclimate variables

Site differences in the PCA ordination plot. Axis 1 (eigenvalue 1.914) grouped composition among plots were clearly shown, while axis 2 (eigenvalue 0.086) separated composition between each site with time period for pollination (09:00-15:00). Two distinct groups of Fig. 4 were clustered into: group I comprising Mae Gar (09:00-12:00), Larn Sang, Dong Larn and Khao Soi Dao (09:00-11:00) and Mae Tha (09:00-10:00) seed orchards. From the sample data of group I, the spread of volume of nectar and forenoon time period on the ordination were positive correlated with relative humidity variables. Group II (afternoon periods group), sugar concentration of nectar relating to an ordination that was positive correlated with temperature, LAI and PAR (e.g. Mae Gar, Dong Larn and Khao Soi Dao (13:00-15:00), Larn Sang (12:00-15:00) and Mae Tha (11:00-15:00) seed orchards). When relationship between floral morphology i.e., floral nectar and microclimate (PAR, LAI, temperature and relative humidity) was investigated, it was found only temperature that affected both sugar concentration and volume of nectar indicating that temperature is a factor influencing the sugar

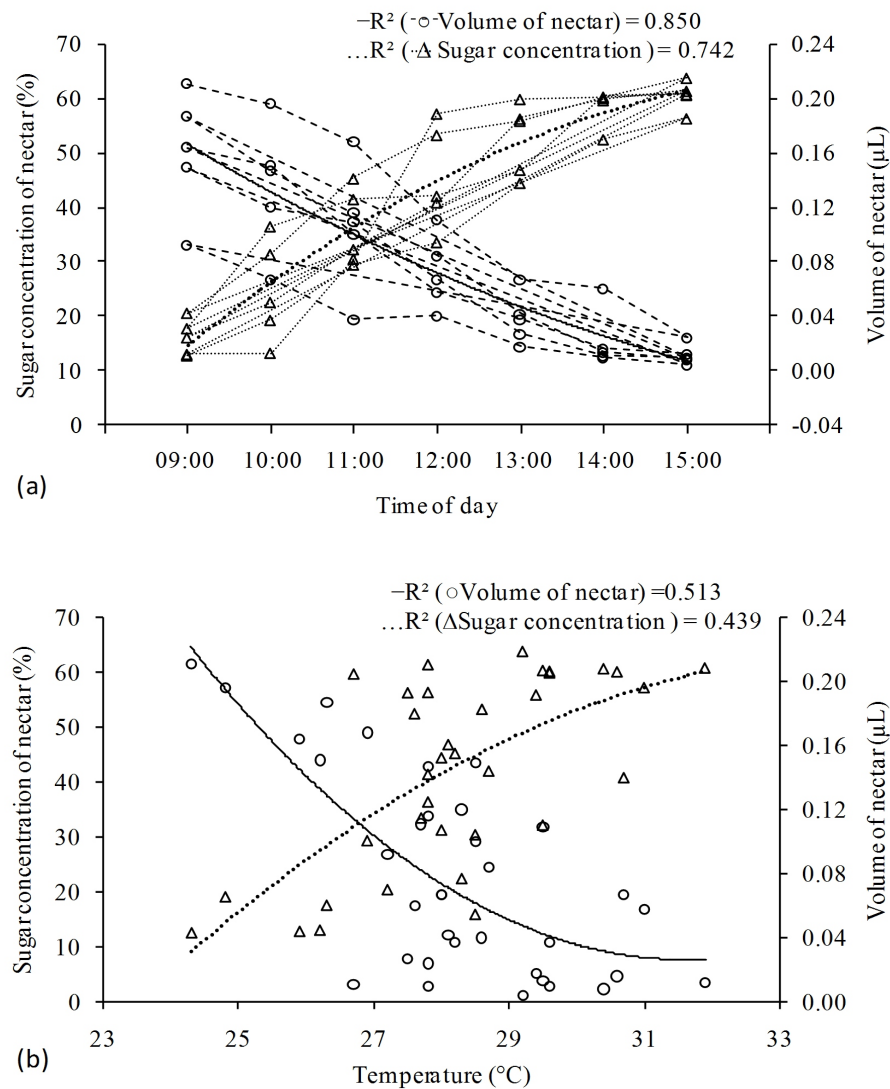


Fig. 3 Relationship between variation of sugar concentration and volume of nectar flower (a) in each period for pollination of teak flowers during 09:00 to 15:00 and (b) relates in air temperature

Concentration and quantity of nectar in teak flowers. Thus, temperature tended to be an important factor in determining the effective pollination period, stigma receptive and pollen germination [2, 5]. The most favorable temperature was 25 °C for maximum fruit set in *Olea europaea* L. [5]. Teak flowering occurred during the rainy season, at midday (11:00-13:00) stigma of teak is most receptive [24]. Therefore, the microclimate, especially sunlight and temperature had been necessarily for visiting behavior of teak insect pollinators. In contrast, insect activities on a rainy day or cloudy day were less than on a sunny day. However, high temperature on sunny days may cause drying of the stigmatic surface in less effective pollination [24]. Extreme temperature can cause seed abortion and reducing fruit setting [5, 22].

In conclusion, we only indicated that the floral characteristic of teak is actually varied due to the environmental factors from the different period at intervals and habitat types. We also showed that the floral trait of each site responded to microclimate. Low fruit set or rate of fruit abortion of teak is caused by variation of environmental factors or floral trait. While, low fruit set in some area may be due to low or lack the major insect pollinators [25], which insects are necessary and important for improving pollination and fruit production of teak [16, 24, 26, 27].

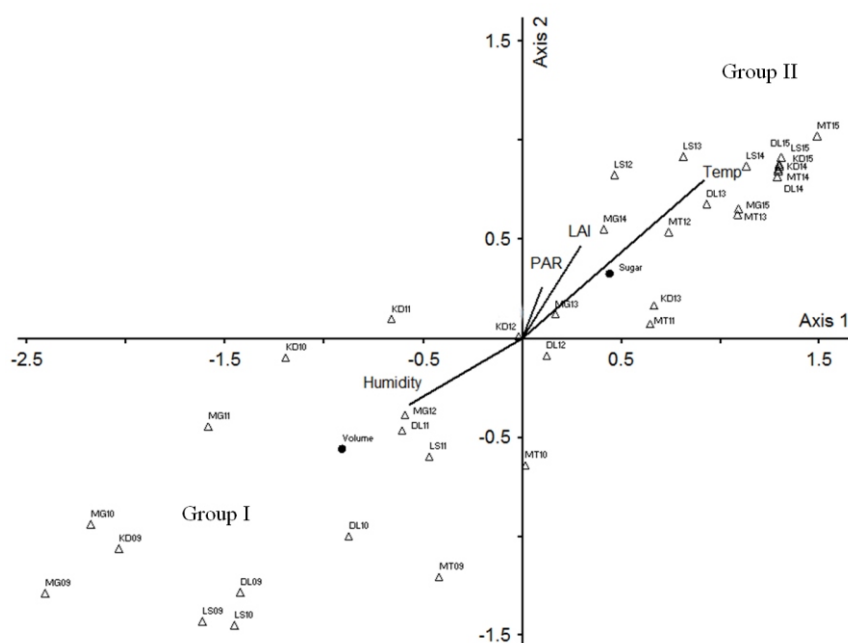


Fig. 4 Principle correspondence analyses (PCA) ordination of each site with time of pollination period (09:00-15:00), showing relationships of the four significant explanatory variables. Triangles refer to sites with times (for abbreviations see Fig. 1). Solid circles refer volume of nectar (volume) and sugar concentration of nectar (sugar). Lines refer to the environmental variables: PAR - photosynthetic active radiation; LAI - leaf area index; Temp - temperature; Humidity - relative humidity. The lines of each factor represent the direction and relative strength of these canonical variable

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