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RECENT HAZE EPISODES AND THEIR IMPLICATIONS ON GROWTH OF *PONGAMIA PINNATA* AND *EUGENIA GRANDIS*

E. Philip

Forest Research Institute Malaysia, Kepong, 52109 Kuala Lumpur, Malaysia

Haze is a phenomenon caused by huge amounts of fine dust or salt particulate, which float in the atmosphere. These particles either occur naturally or are caused by human activities. When these particulates accumulate in large quantities, they reduce the light intensity on earth and affect visibility.

Haze occurrence in the urban areas in Malaysia, especially in the Klang Valley, has become a common feature over the last two decades. It usually occurs during the south-west monsoon season (MMS 1995). During this time, the air becomes very stable thus reducing the atmospheric circulation that could disperse and dilute suspended particulates and pollutants.

Lately, the occurrence of dense haze over the country has been a great concern. At least four such episodes have been observed during this decade. These occurred in August 1990 (Sham *et al.* 1991), June till October 1991 (Cheang *et al.* 1991), August till October 1994 (MMS 1995), and June till October 1997 as observed in this study. These dense haze were due to the injection of suspended ash particulates from the volcanic eruption in Philippines and winds of suspended smoke from forest fires in neighbouring countries (MMS 1995).

To document the effects of haze on vegetation, physiological parameters of two popular urban tree species, namely, *Pongamia pinnata* and *Eugenia grandis*, were recorded before and during the dense haze periods in 1994 and 1997. They were planted as avenue trees in the Sultan Sallahuddin Mosque compound in Shah Alam, which lies at a latitude of 03° 06' N and forms part of the Klang Valley conurbation. Stomatal conductance and net CO_2 uptake were measured. Sampling was conducted between 9.00 till 11.00 a.m. Photosynthetic rates were determined using an infrared gas analyser (ADC LCA4, UK) while stomatal conductance and photon flux density were determined using a steady state porometer (LICOR 1600, USA). Fully expanded leaves were used to determine the photosynthetic rates. These experiments were conducted with six replicates and each replicate had three samples. Data obtained were analysed using a two-way analysis of variance. Sunshine hours and solar radiation were provided by the Malaysian Meteorological Services while particulate matter (PM_{10}), was provided by the Department of Statistics (Anonymous 1998).

During the hazy spells, the daily global solar radiation was reduced to 25% below the long-term mean during the months the sky was enveloped by the haze. The number of sunshine hours had been reduced between 20–45% against the long-term average (Figure 1). During the intense haze period, number of sunshine hours was below five and the average daily global radiation differed by a factor of 4.0.

Life on earth is maintained by the flow of energy radiated from the sun. Likewise, plants, by means of photosynthesis, capture the solar energy to produce energy for carrying on vital processes. Therefore, a reduction in photon flux density (PFD) would indicate a reduction in photosynthesis and stomatal conductance. Riddoch *et al.* (1991) reported that carboxylation rate, dark respiration and light-saturated photosynthetic rate were sensitive to light.

An average of 45% of the incoming solar energy falls within the spectral range of 380–710 nm (PFD), which is the range utilised for photosynthesis by plants (Larcher 1995).

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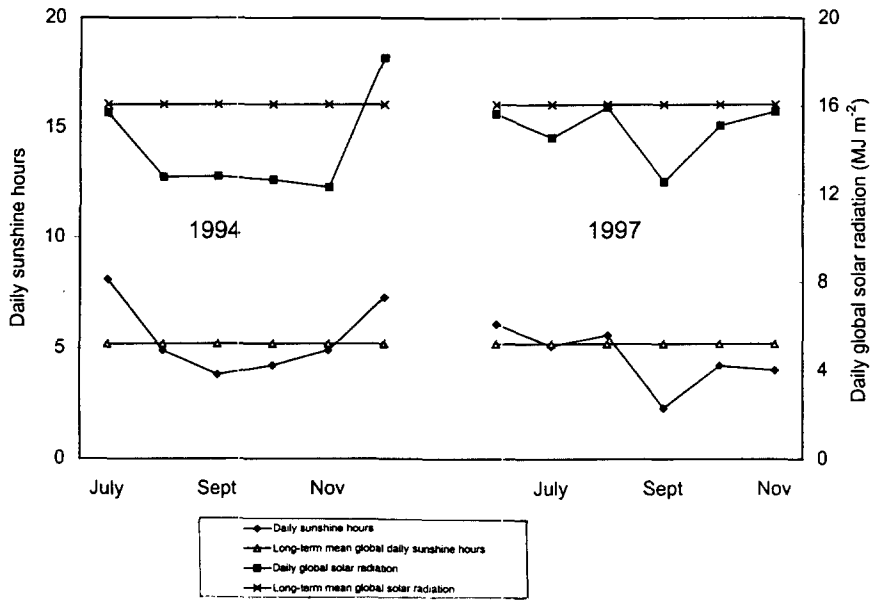

Figure 1. The effects of haze on daily sunshine hours and daily global solar radiation. Haze occurred between August till October 1994 and June till October 1997. Dense haze occurred between September to October in both years.

In this study, PFD reduction varied between 40–75% and depended on the haze density (Figure 2). Tang *et al.* (1996) reported a 50% reduction of PFD at 40 m above ground during the 1994 haze episode at Pasoh Forest Reserve, Negeri Sembilan, Malaysia. Elsewhere, it was reported that haze resulting from distant forest fires reduced solar radiation at almost all spectra (Bailey *et al.* 1989).

As mentioned earlier, the reduction in sunlight intensity was due to increased particle in the atmosphere. PM_{10} almost doubled during the hazy period (Figure 3). Particulate can reduce visibility and solar radiation through both light absorption and scattering (USEPA

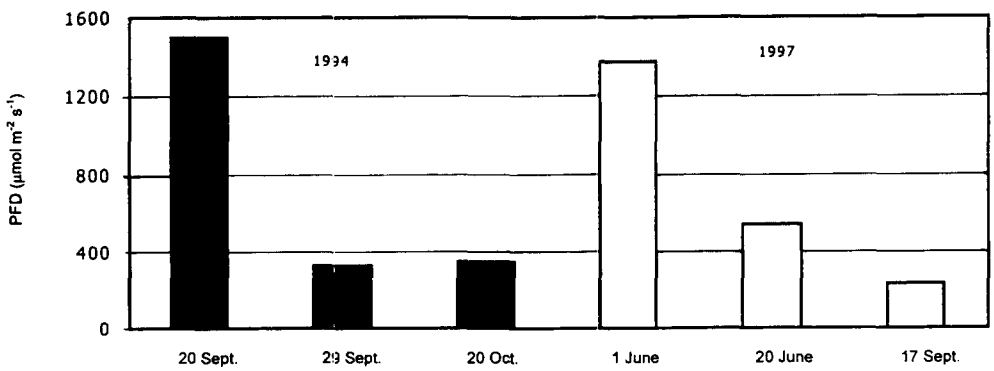

Figure 2. The effect of haze on photon flux density. 20 September 1994 and 1 June 1997 were sunny days while the rest were dense haze days.

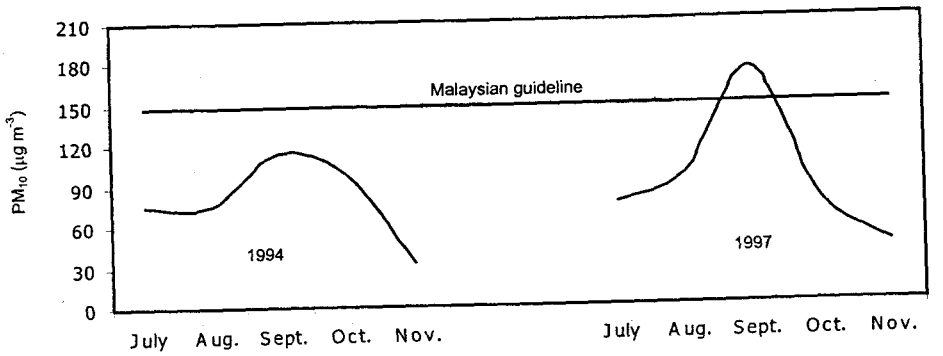

Figure 3. The particulate matter (PM_{10}) composition during the haze episodes in Shah Alam

1982). When solar radiation is reduced, less energy is available for photosynthesis in plants. In addition, increased particulate matter in the air could also cause clogging of stomata. Thompson *et al.* (1984) reported that a dust load of 10 g m^{-2} reduced photosynthesis by 17% and increased leaf diffusion resistance by 42%.

The consequence of reduced PFD on vegetation is a decline in the physiological parameters, namely, photosynthetic capacity and stomatal conductance. Both these parameters are key determinants of plant productivity. Cell division depends more closely on photoassimilate supply than on availability of water and nutrients. Therefore, final leaf size can be limited by photosynthetic acitivity (Kriedemann 1986). On the other hand, stomata play a pivotal role in controlling the balance between water loss and carbon gain. Measurements of stomatal conductance/resistance to CO_2 and H_2O transfer between the atmosphere and mesophyll area in leaves are important to assess the biomass production. In this context, where trees are planted for ornamental purposes, the desired architecture and form may not be achieved due to insufficient matter investment from photosynthesis.

Measurements made during the dense haze period revealed that both photosynthetic rate and stomatal conductance were reduced between 20–50% compared to that during the non-haze periods (Figures 4 & 5). The month of September for both years saw the highest percentage of photosynthetic and stomatal conductance reduction, which also coincided with very dense haze. Comparing between 1994 and 1997, the percentage reduction was almost similar. The decline in these rates was attributed to the fact that the photon flux density reduced to levels below the light saturation for photosynthesis.

Therefore prolonged haze has its impact not only on human health but also on plants. The reduced light intensity reduces the photosynthetic capacity within the plants and thus limits the carbon gain in these trees. Consequently, long periods of haze may weaken and eventually affect the vitality of landscape trees. Thus, trees in urban areas, which are subjected to harsh growing environments, may subsequently succumb to other secondary problems like pest and disease attacks.

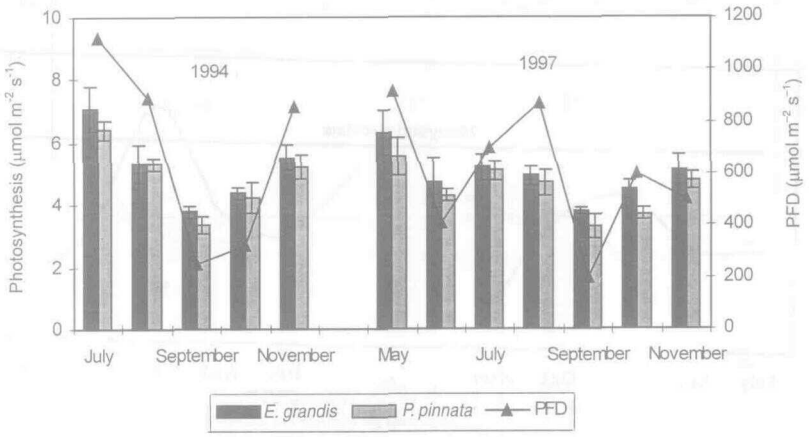

Figure 4. The effect of haze on photosynthesis (± S. E.). Haze occurred between August till October 1994 and June till October 1997. Dense haze occurred between September till October in both years.

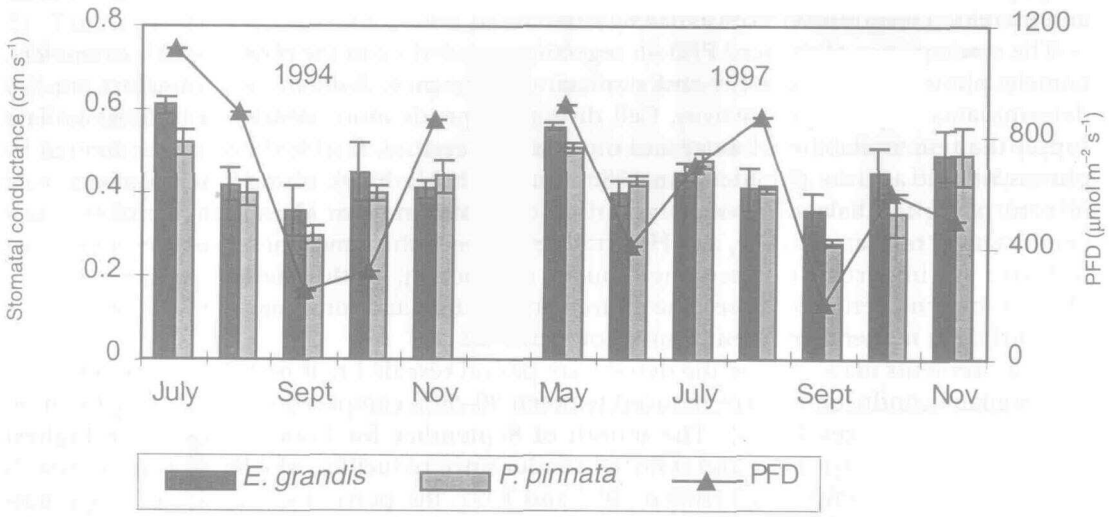

Figure 5. The effect of haze on stomatal conductance (± S. E.). Haze accurred between August till October 1994 and June till October 1997. Dense haze occurred between September till October in both years.

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