5. DISCUSSION

5.1 Methodology

Among the wide range of methods used to determine lead contents of leaves, flame and electrothermal atomic absorption spectrometry have become two of the most popular and reliable techniques (Puchades *et al.*, 1989). This method requires that the organic part of the sample be destroyed by either a wet or a dry ashing procedure.

In this research, the chemical analysis of lead in plant material is described using atomic absorption spectrometry with evolution of volatile hydride after a wet digestion.

The lead hydride generation in a lactic acid-potassium dichromate medium was applied to the determination of lead in plants. The effect of different acids on the lead hydride generation in potassium dichromate oxidant medium was studied. Lactic acid-potassium dichromate was found to give optimum lead hydride generation (Madrid *et al.*, 1990). One of the advantages of this method is its high sensitivity which is 0.44 ng.

5.2 Recovery

The average measured recoveries for the sample analysis of lead in the five species were 103%, 101%, 94%, 93%, and 91% respectively (see Table 4.5) which reflect the reliability of analysis process.

5.3 Reference Material Measurements

In order to further test the stability and reliability of the analysis method for lead determination, two reference materials, rye grass and hay powder, were also analyzed using the same procedure as samples. Certified reference materials were supplied by International Atomic Energy Agency and the European Community Bureau of Reference. A wide range of sample treatment methods was applied in establishing the CRMs. And methods of final determination were slurry cold vapor, flame or electrothermal atomic absorption spectrometry. Compared to the verified values of two reference materials, it can be seen that the measured values of reference materials in my analysis are a little bit high. However, the measured values are within significance level 0.05 (Table 4.6). Thus, the digestion and analysis method in this study was effective and reliable.

5.4 Curvilinear Calibration Regression for Calculation of Concentrations

Usually, the calibration curve for lead analysis is linear regression. However, in a relatively wide range of concentrations of lead, linear regression does not fit well to AAS data. This being the case, curvilinear regression was applied in calibrating calculation of lead contents in the samples.

5.5 Comparison of Lead Contents Among Five Species

Considering the content of lead in dust attached to the surface of plant leaves, etc., each sample was divided into two groups. One is that in which the sample of leaves was washed by distilled water called the washed sample. The other one is called the unwashed sample.

Figure 5.1 shows the levels of lead in unwashed leaf samples of five species as collected in December (dry season) at all 13 study sites. It is clear that there is a great difference of lead contents in five species at each site. *Bougainvillea* almost has the highest concentration of lead in all 13 sites. Similarly, this result was observed in July (rainy season) also in unwashed samples (Figure 5.2).

The comparison of lead concentrations in washed samples in December and July (dry and rainy seasons) is shown in Figures 5.3 and 5.4 respectively. Similar results are shown for unwashed samples, i.e. *Bougainvillea* still has the highest concentration of lead at all study sites.

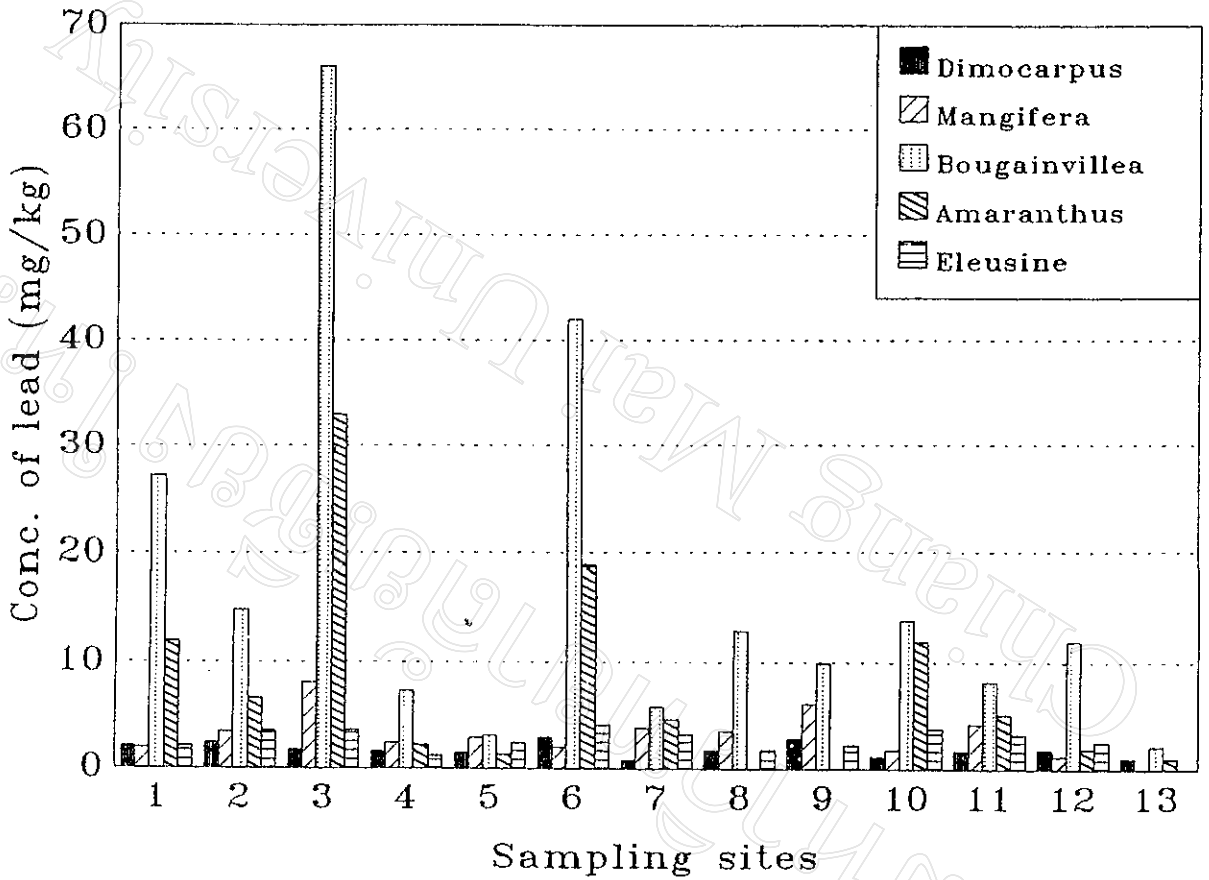

Figure 5.1 Lead concentration in unwashed samples in December, 1995

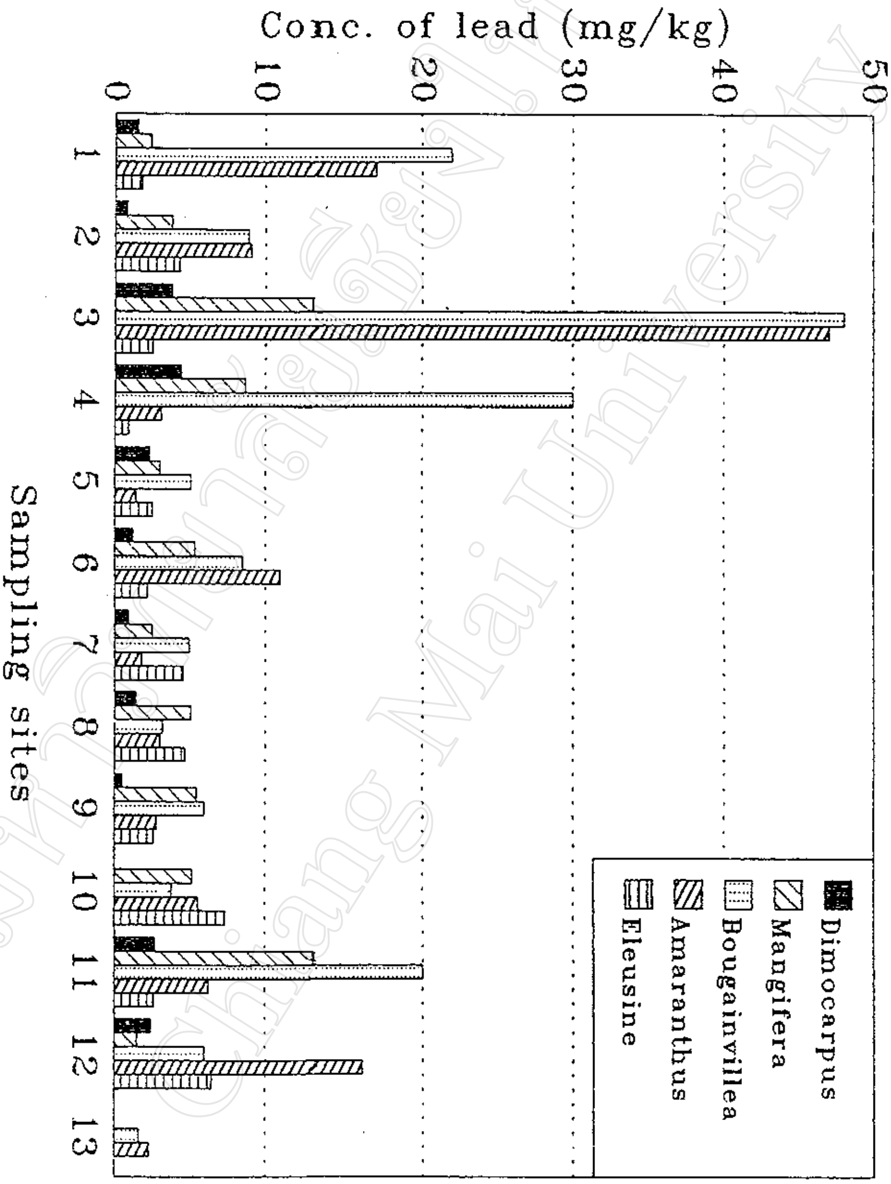

Figure 5.2 Lead concentraion in unwashed samples in July, 1995

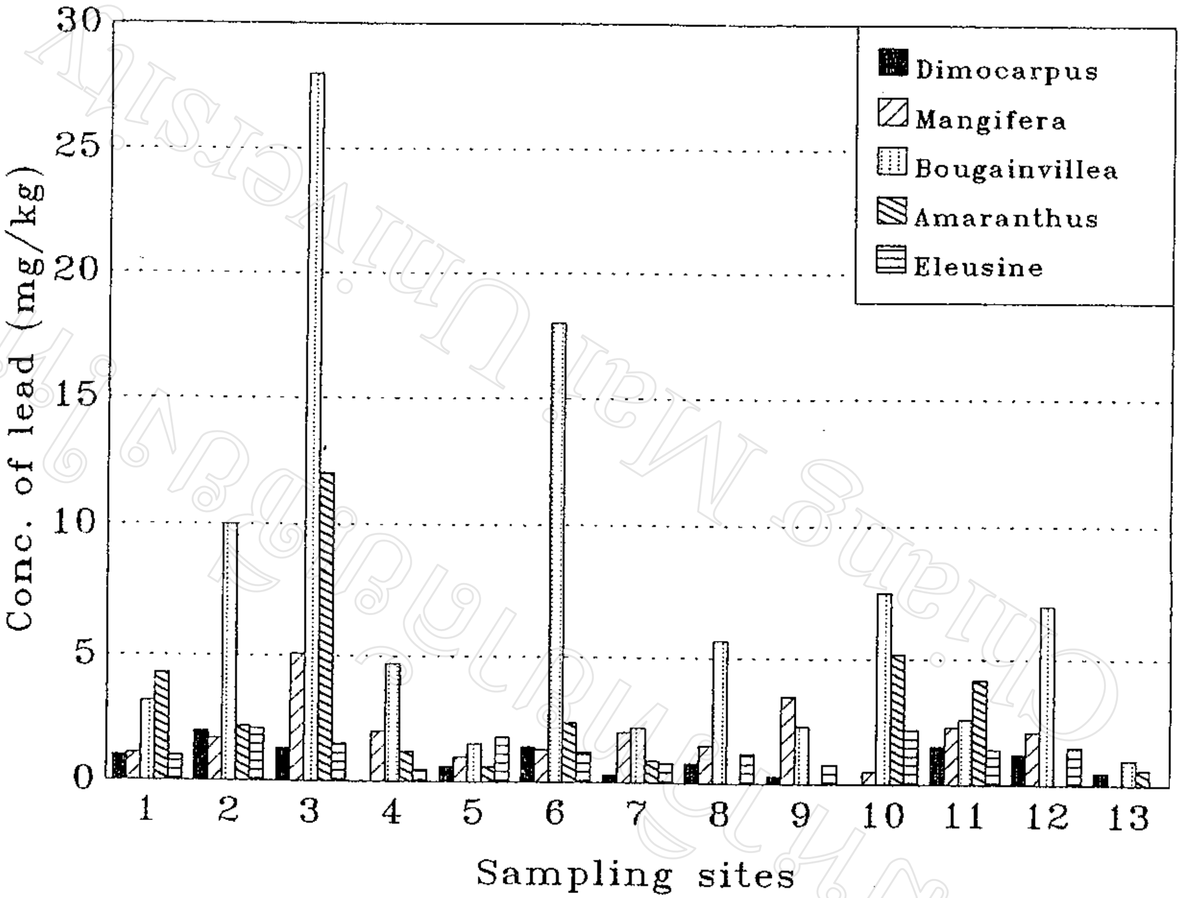

Figure 5.3 Lead concentraion in washed samples in December, 1995

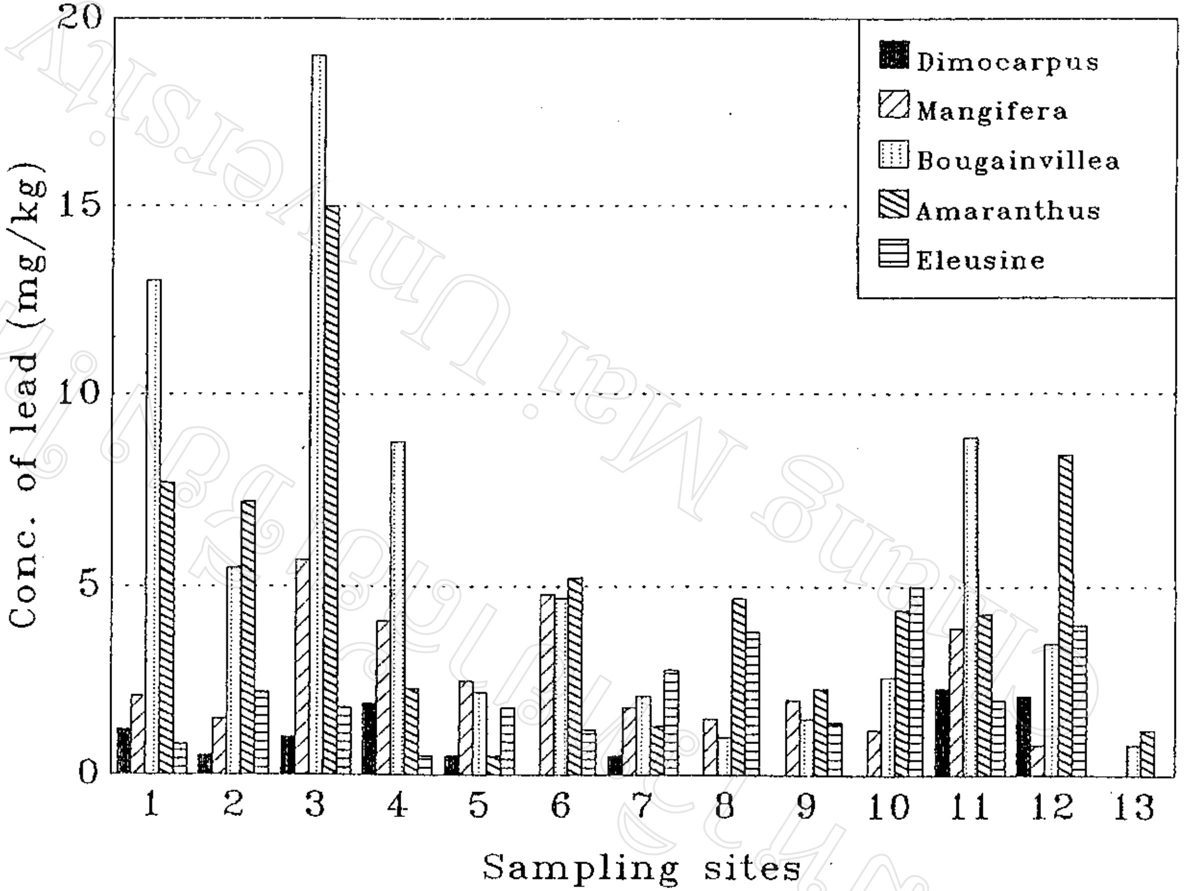

Figure 5.4 Lead concentraion in washed samples in July, 1995

Further comparison was done in relation to the difference of lead concentration among species by statistical program SPSS. The statistical analysis showed the differences among the five species were significant for both washed ($p<0.01$) and unwashed ($p<0.0001$) samples in each season (Appendix B1 and B2).

This work indicates that *Bougainvillea* has a high capacity for lead accumulation.

A number of studies related to metal accumulation in different plant species have shown that the accumulation is totally species-dependent since different species absorb metals at different rates.

Since plants can absorb trace metals from both the soil and atmosphere, the use of plants materials as monitors of airborne lead may be complicated where plants are rooted in soil. Moreover, in areas near heavy traffic where samples are collected, the soil becomes enriched with lead which plants can absorb from the soil by their roots and subsequently translocate to other parts of plant. Lisk (1972) pointed out that metal absorption from the soil by plants depends on the nature of the plant, i.e., its size, growth rate, extent and depth of rooting, transpiration rate, and nutritional requirements. Furthermore, he observed that trees are especially effective in absorbing many trace metals from great depths and translocating them to the leaves.

However, there is nothing known about passive or active assimilation of lead by *Bougainvillea* from soils polluted with lead.

Rabinowitz (1972) reported that rigorous washing of plant samples may remove a large fraction of the aerial deposits.

Comparing the contents of lead between the washed and unwashed samples for *Bougainvillea*, it was found that at each sampling site, lead concentrations in unwashed samples were much higher than in washed ones. However, by analyzing the difference of lead concentrations between unwashed and washed samples, it can be found that most of the lead was contained inside the sampled plants both in December and July (dry and rainy seasons) (Figures 5.5 and 5.6). Also, it can be seen that a site with high content in unwashed samples has higher content in washed samples. This suggests a relationship between the content of airborne lead and accumulation of lead in *Bougainvillea*.

Probably, *Bougainvillea* uptakes lead directly from the air. This means *Bougainvillea* has a high accumulation rate of lead.

5.6 Influence of Distance from Pollution Source on Lead Contents in Plants

As mentioned before, there have been many of studies conducted concerning the influence of distance on contaminant content in leaves. Wong and Tam (1987) used two different species of *Brassica* (Cruciferae) as bioindicators for detection of lead contamination caused by road traffic. In their study at various distances from a major thoroughfare, soil and plants were sampled and atomic absorption spectroscopy used to determine their lead content. The plant samples were differentiated into leaves,

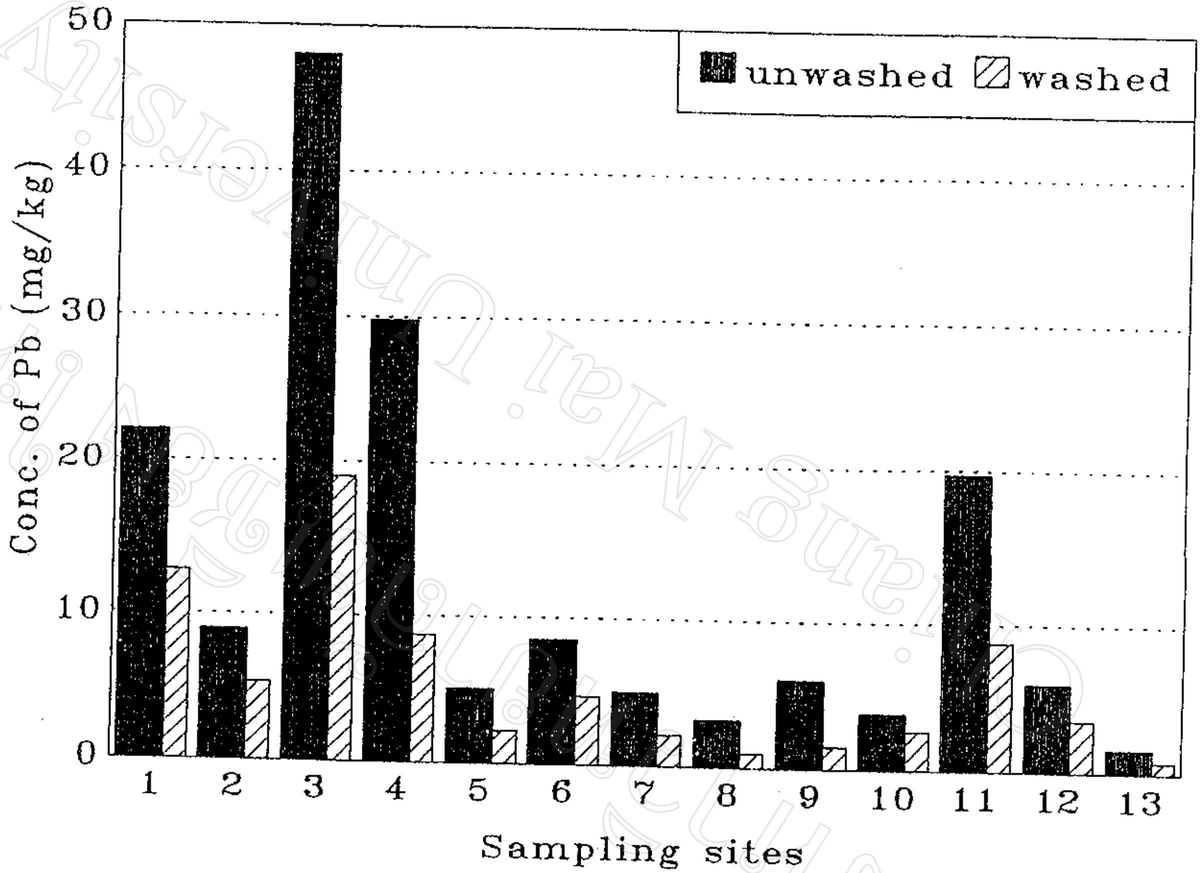

Figure 5.5 Lead content of washed and unwashed samples for Bougainvillea in July, 1995

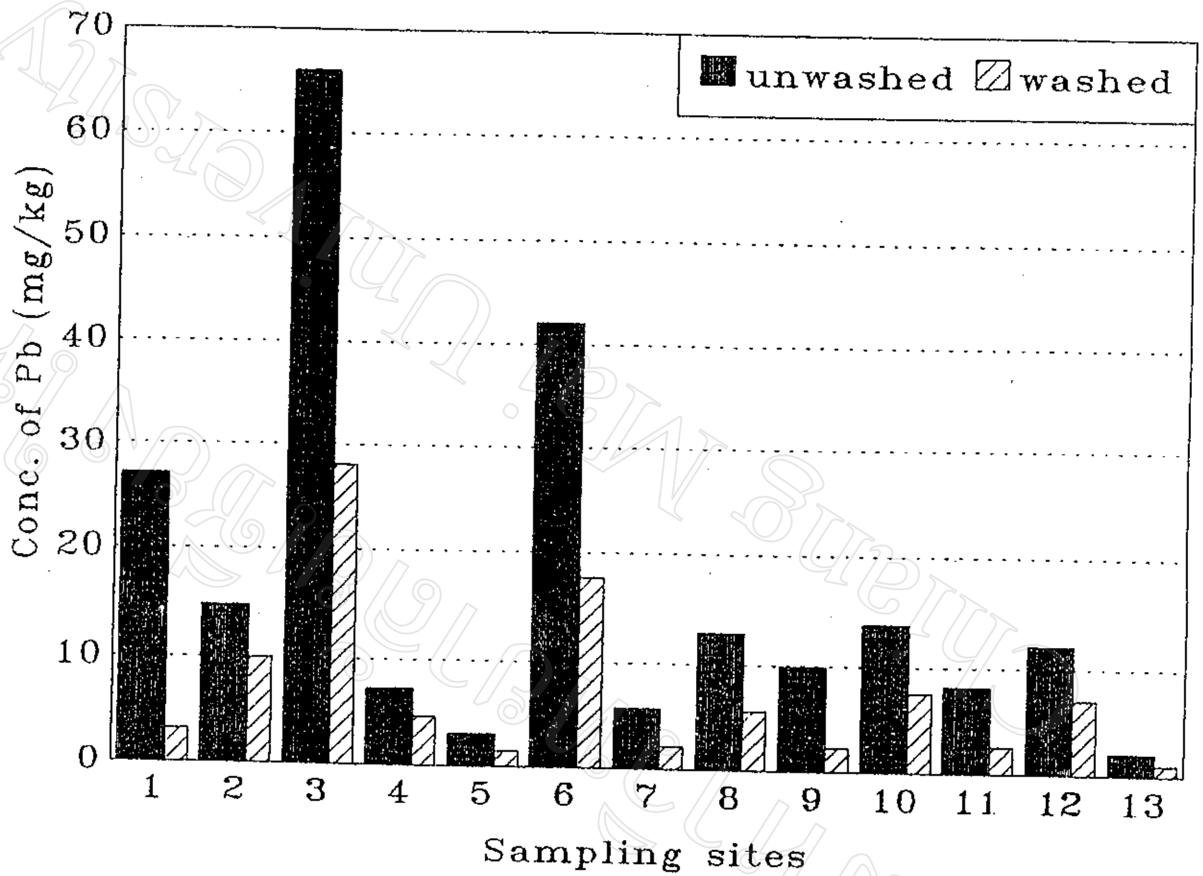

Figure 5.6 Lead content of washed and unwashed samples for Bougainvillea in Decmber, 1995

shoots, and roots that were unwashed, washed with distilled water, or cleaned with a detergent. The result showed that the content of Pb in leaves of *Brassica alboglabra* was 80 ppm when in the distance of 1 meter away from the motorway, and 30 ppm at 200 meters.

In this study *Dimocarpus* and *Mangifera* were relatively far from the busy road. *Bougainvillea*, *Amaranthus* and *Eleusine* were just beside the road. From Tables 4.1 to Table 4.4 it is clear that the lead contents in samples of *Bougainvillea*, *Amaranthus* and *Eleusine* are higher than those in *Dimocarpus* and *Mangifera* in both unwashed and washed groups. The lead contents in the samples probably are related with the distance from contaminant sources, which caused higher content in *Bougainvillea*, *Amaranthus* and *Eleusine* than *Dimocarpus* and *mangifera*. However, this comparison is taken between the different species, further research should be done in relation to distance in same species.

5.7 Influence of Seasonal Variation on Lead Contents in Plants

From Figures 5.7 and 5.8 the significant difference of lead contents in the samples between December and July (dry and rainy season) is not observed. Furthermore, by applying statistics program SPSS, the results show no significant difference (P>0.05) (see Appendix B3 and 4). In this study there was no correlation between the lead content in the plants and seasons. There are several factors which might have been expected to affect the correlation possibly such as sampling conditions, weather condition, plant locations and situations.

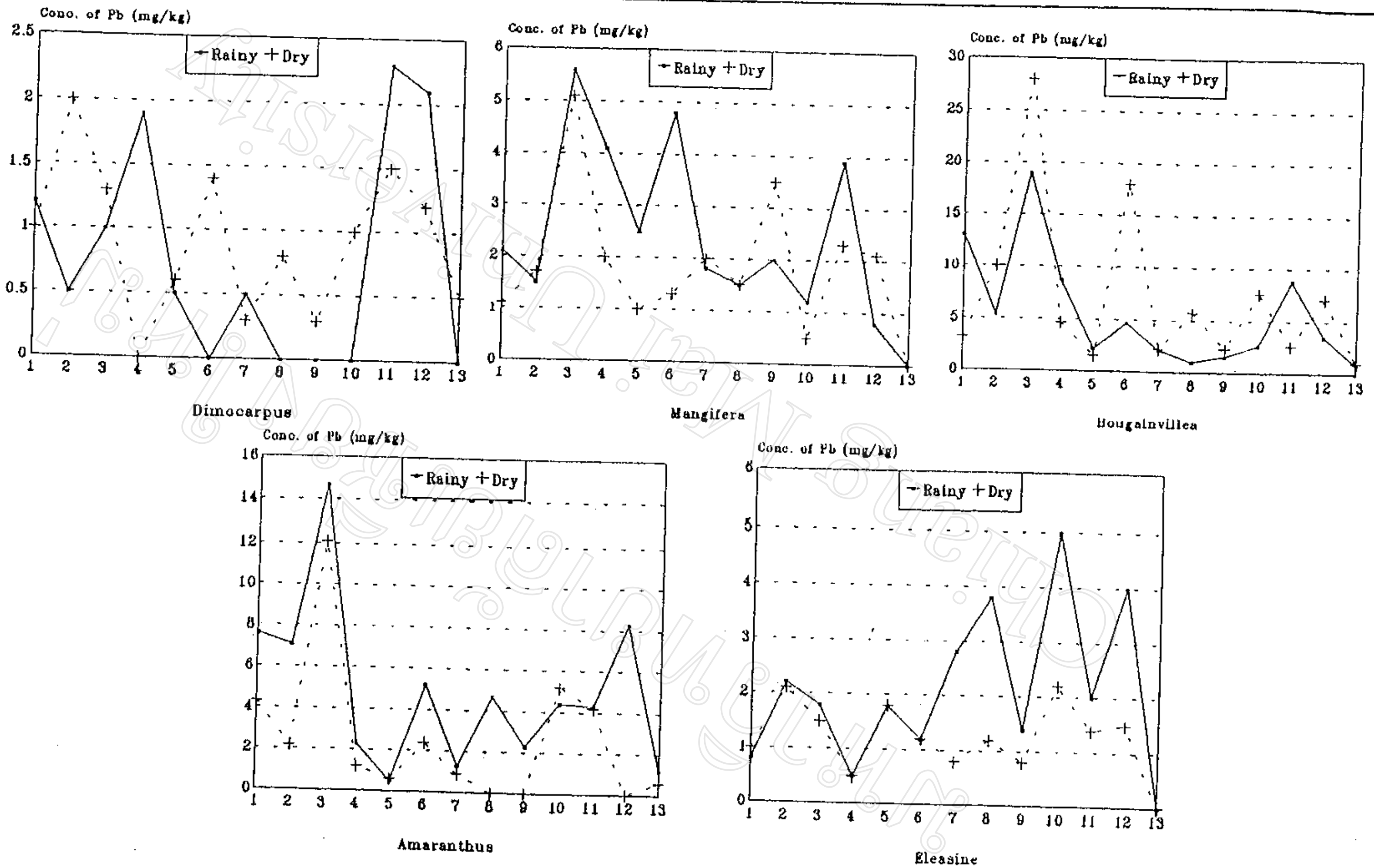

Figure 5.7 Comparison of Pb level in washed samples between seasons

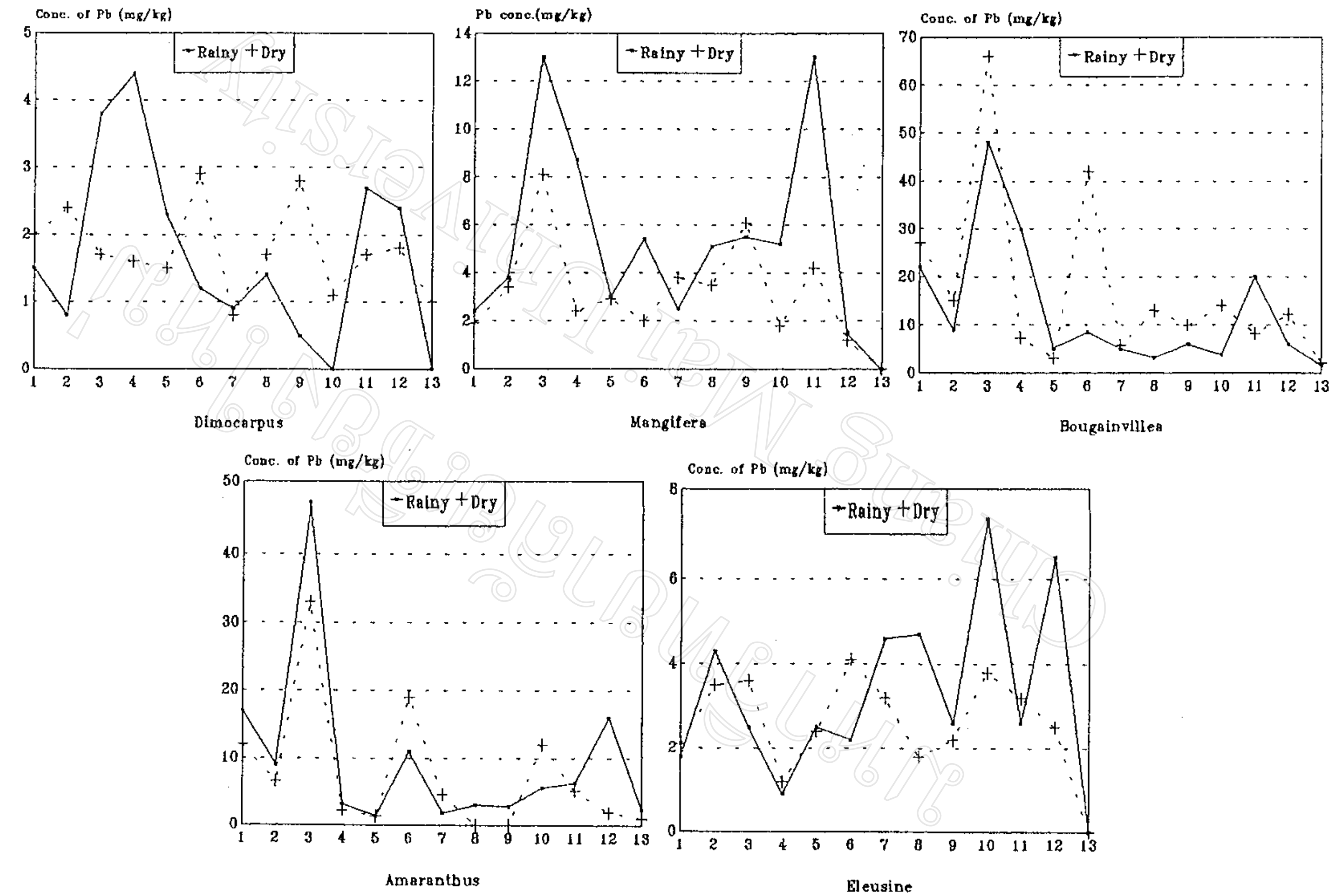

Figure 5.8 Comparison of Pb level in unwashed samples between saesons

5.8 Bioindicators for Monitoring Lead Pollution in Chiang Mai City Air

Biological monitoring is based on eco-physiological methods and the use of tissue-related criteria. This refers to the measurement of lead content in plants and other techniques that permit non-destructive assessment of the condition of plants. In spite of the fact that special equipment, such as an atomic absorption spectrometer, is also required, techniques exist that are acceptable in terms of cost and labor, especially considering that these parameters exhibit a high degree of sensitivity to environmental pollution.

Until now, lead uptake by different plant species, especially trees, has been unclear (Smith and Brennan, 1984; Kabata and Pendias, 1992).

Mosses and lichens are frequently chosen to monitor heavy metals. However, because of their slow growth, their low growth forms which closely follows the substrate on which they are found, and difficulties in distinguishing between the annual growth zones, it is rarely possible to draw conclusions on contaminant absorption from the soil or the air, or during a defined time span. Moreover, mosses and lichens do not grow well in highly polluted areas. Due to these reasons, it is necessary to screen and select suitable plant species for airborne lead pollution.

In Chiang Mai, a rapidly expanding large city with increasing air pollution, a few studies have been made regarding bioindicators for environmental pollution. Nothing has been done in relation to biomonitoring of airborne lead.

However, the environmental problem is receiving more and more attention in Chiang Mai City. Work related to environmental biomonitoring has been undertaken in recent years. A case study carried by Yang (1994) showed that *Eichhornia crassipes* and *Ipomoea aquatica* can both concentrate heavy metals from water and suggested that they be used for monitoring water pollution.

On the basis of results of this work, *Bougainvillea* is suitable as a sensitive and also an accumulative bioindicator for monitoring lead pollution in Chiang Mai City air.

As a type of ornamental plant, *Bougainvillea* is one of the most favorite species. It is very common and grows everywhere in Chiang Mai as well as the rest of Thailand. So, the characteristics of *Bougainvillea* give it the advantage that it is easy to collect samples and thus it is a good indicator to monitor airborne lead. Also, it can be used as bioindicator for both active and passive monitoring.

5.9 Risk Assessment by Using Bioindicators at Sampling Sites

Lead is a key pollutant in Chiang Mai City since there are so many available sources. In particular, airborne lead pollution is a serious problem due to rapid development of roads and dramatically increasing numbers of motor vehicles. Lead-induced health effects are known to occur in children and adults across a wide range of exposure. Because of the high toxicity of lead to children, the American Academy of Pediatrics have recommended decreasing the exposure limit value of 30 μg/dl of blood in 1978 to 25 μg/dl in 1985 and 10 μg/dl in 1992. So, it is urgent that the concentration of lead in the air be monitored.

Based on the discussion above, *Bougainvillea* could be a good bioindicator for airborne lead monitoring. In terms of concentration of lead in *Bougainvillea*, there was a great difference of lead content in the samples at different sampling sites, which roughly reflects the situation of present air lead pollution in Chiang Mai City.

From tables 4.1 to 4.4, it can be seen that the concentration of lead is up to 66 mg/kg at site 3. Even for washed samples, there is still a highest concentration of 28 mg/kg at site 3. And concentrations of lead in *Bougainvillea* at most sites are more than 5.0 mg/kg. However, up until now there are still neither standards nor reference data for *Bougainvillea* which can be used for assessing the extent of air lead pollution and risks to the health of animals or humans.

A comparison was made between this research and a recent study regarding air lead pollution which was carried out in Greece (Sawidis,1995). In the latter research, eight species of trees were used as biological indicators. The results showed that the highest concentration of lead is 14.5 mg/kg in *Populus alba*, and the concentration of lead for eight species in most study sites is less than 1.5 mg/kg. It means that the situation of air lead pollution is more serious in Chiang Mai City than in the Greek City considering the lead content in plants. However, since this comparison was made between the different species, further study is needed to assess the present status of air lead pollution.

Further comparison of lead content among the sites indicates that site 3, along the Super highway, is the highest both in the unwashed and washed groups both in December and July (dry and rainy seasons). From Table 5.1, site 3 was the most contaminated with Pb. It is followed in December by site 6 which is located beside Mae Ping River. And in

July it is followed respectively by site 4 in unwashed group and site 1 in washed group. The increased Pb content in the leaves from these sites was caused probably by the heavy traffic. However, the relationship between lead contamination and the number of vehicles can not be firmly established due to lack of the data about vehicles per day. Considering the control site 13, which is just about one kilometer off a main road, the lead contents in all samples are the least with concentration being less than 0.5 mg/kg in most samples. This further confirms the hypothesis that the concentration of lead in plant species from sites with higher content of lead in the air will be higher than those from sites with less traffic.

Table 5.1 Site Ranking of Lead Content in *Bougainvillea* at All Sampling Sites

Group	Seasonal Variation	Site number (Highest to lowest concentrations)
Unwashed	December (dry)	3, 6, 1, 2, 10, 8, 12, 9, 11, 4, 7, 5, 13
	July (rainy)	3, 4, 1, 11, 2, 6, 9, 12, 5, 7, 10, 8, 13
Washed	December (dry)	3, 6, 2, 10, 12, 8, 4, 1, 11, 9, 7, 5, 13
	July (rainy)	3, 1, 11, 4, 2, 6, 12, 10, 5, 7, 9, 8, 13