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Tolerance Levels of Roadside Trees to Air Pollutants Based on Relative Growth Rate and Air Pollution Tolerance Index

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Motor vehicles release carbon monoxide, nitrogen dioxide, sulphur dioxide, and particulate matters to the air as pollutants. Vegetation can absorb these pollutants through gas exchange processes. The objective of this study was to examine the combination of the relative growth rate (RGR) and physiological responses in determining tolerance levels of plant species to air pollutants. Physiological responses were calculated as air pollution tolerance index (APTI). Eight roadside tree species were placed at polluted (Jagorawi highway) and unpolluted (Sindangbarang field) area. Growth and physiological parameters of the trees were recorded, including plant height, leaf area, total ascorbate, total chlorophyll, leaf-extract pH, and relative water content. Scoring criteria for the combination of RGR and APTI method was given based on means of the two areas based on two-sample t test. Based on the total score of RGR and APTI, *Lagerstroemia speciosa* was categorized as a tolerant species; and *Pterocarpus indicus*, *Delonix regia*, *Swietenia macrophylla* were categorized as moderately tolerant species. *Gmelina arborea*, *Cinnamomum burmanii*, and *Mimusops elengi* were categorized as intermediate tolerant species. *Lagerstroemia speciosa* could be potentially used as roadside tree. The combination of RGR and APTI value was better to determinate tolerance level of plant to air pollutant than merely APTI method.

Key words: air pollutants, tolerance of roadside trees, relative growth rate, physiological responses, air pollution tolerance index

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INTRODUCTION

Vehicles represent a mayor source of air pollutants such as, carbonmonoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and particulate matters. Emission from vehicles tends to increase due to increasing number of vehicles. The implementation of appropriate transportation policy by using minimally polluting automobiles, improving combustion system, and planting roadside vegetation could reduce air pollutants from motor vehicles.

Roadside vegetation based on level road structure at 10 and 150 m from road could reduce NO_2 concentration up to 3.5 and 2.3 ppb, respectively (Nasrullah *et al*. 1994). Reduction of NO_2 concentration by the vegetation might be due to the absorption of the pollutant by its canopy and its dispersion into the planting area. Vegetation absorbed NO_2 through gas exchange processes, and then it was assimilated into nitrogenous compounds and used as the plant major compound to increase its growth (Rowland 1986).

Aclimatization of plants to air pollutants might change their morphological structure such as thicker epidermal cells and longer trichomes (Rangkuti 2003). Physiological response was showed in stomata control mechanism by closing response to noninjurious levels of SO_2 and opening response at noninjurious levels O_3 (Olszyk & Tibbitts 1981).

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Four physiological properties i.e. total ascorbate (AsA) and chlorophyll (Chl) content as well as leaf-extract pH and relative water content (RWC) calculated as air pollution tolerance index (APTI). The APTI value was used to evaluate the susceptibility level of plants to air pollutants (Singh *et al*. 1991). Ascorbate was known as an antioxidant molecul able to detoxify air pollutants (Smirnoff 1996) and it is also able to control cell expansion and cell division (Loewus 1999; Conklin *et al*. 2000). Chlorophyll is essential for the vital process of photosynthesis in green plants. Changes in leaf Chl can serve as relative indicators of environmental quality (Carter & Knapp 2001). The importance of pH in mediating physiological responses to stress was another reason in including it in APTI component (Hartung *et al*. 1988). The tolerance criteria of this method were distinguished between evergreen and deciduous plants.

In determining tolerant plant species to air pollutant, Singh *et al*. (1991) did not examine the plant growth rate; in fact, the growth is expression of plant acclimatization and tolerance to air pollutants (Larcher 1995). Relative growth rate could measure based on increasing of plant height or total leaf area. The plants height could explain RGR since it was affected by light intensity, temperature (T), relative humidity (RH), wind speed, photosynthesis efficiency, and air pollutants (Larcher 1995). Leaf area is one of the most common driving variables in growth analyses (Lambers *et al*. 1998). Therefore, the objective of this study was to examine the combination of the relative growth rate (RGR) and physiological responses in determining tolerance levels of plant species.

MATERIALS AND METHODS

Study Sites. The studies were conducted in two different locations. First, at Jagorawi (Jakarta-Bogor-Ciawi) highway (km 43.5), which was located between 106°48’51" E and 6° 36’20" S, at an elevation ± 280 m above sea level. Jagorawi considered as polluted area (P) due to high traffic volume; several air pollutants parameters in Jagorawi were higher than that of National Ambient Air Quality (Utami 2006). Second, Sindangbarang field was located between 106°46’0" and 6°35’40"S, at an elevation ± 222 m above sea level. This field considered as unpolluted area (U) having air pollutants parameters lower than National Ambient Air Quality (unpublished data).

Preparation of Sample Plants Experimental. We used eight plant species that were usually used as roadside tree planting. Those were *Pterocarpus indicus* Wild (*angsana*), *Lagerstroemia speciosa* L. (*bungur*), *Casuarina sumatrana* Jungh (*cemara laut*), *Delonix regia* Bojer (*flamboyan*), *Gmelina arborea* Roxburg (*jati putih*), *Cinnamomum burmanii* Nees (*kayu manis merah*), *Swietenia macrophylla* King (*mahoni*), and *Mimusops elengi* L. (*tanjung*). All tree species were obtained from Bogor Botanical Garden.

All plants were grown in 30 cm diameter, 30 cm height plastic pots. Media was a mixture of compost and soil (1:3 v/v). The plants were grown for six months until reaching 120-150 cm in the green house of Bogor Agriculture University at Bogor.

Experimental Set Up. The experiment was conducted from August to November 2006. The experimental pots were placed at the green belt separator between two roads of Jagorawi highways. The pots were arranged in two rows separated about three meters between the rows. Each row was consisted of twenty four pots (eight pots in three replicates). The distance between two pots was 1 meter and between two replicates in the same rows was 50 m, as shown at Figure 1. Air pollutant parameters were measured at the middle of the rows. In Sindangbarang field, twenty four pots consisted of three replicates were placed at 100 m^2 wide area. The pots were arranged in six rows and the distance between the rows was two meters. Each replicates was consisting of eight pots arranged in two adjacent rows.

Air pollutant concentration at Jagorawi highway and Sindangbarang field was measured in two replicates at the same day between 11.00 until 13.00. Air quality parameters and their method of analysis were showed at Table 1. Microclimate data at Sindangbarang was obtained from the Climate Station in Sindangbarang, Bogor. Traffic volume on Jagorawi highway was measured in two days (12-13 November 2006) by manual counting from 07.00-17.00 within two hours interval.

Plant Growth and Physiological Response Analysis. Relative growth rate was calculated based on plant height and or total leaf area. The plant height was measured in each week within 14 weeks. The total leaf area was measured at week 4, 8, 12, and 14 for all studied species except in

Table 1. Air quality parameters and their analysis method by Lodge (1988)

Parameter	Method of analysis
NO_2	Griess-Saltzman
NH_3	Indophenol
SO_2	Pararosanilin
H_2S	Methylen Blue
Total particulate	Gravimetri
Pb	AAS
CO	Aspirometer
O_3	Neutral Buffer Pottasium

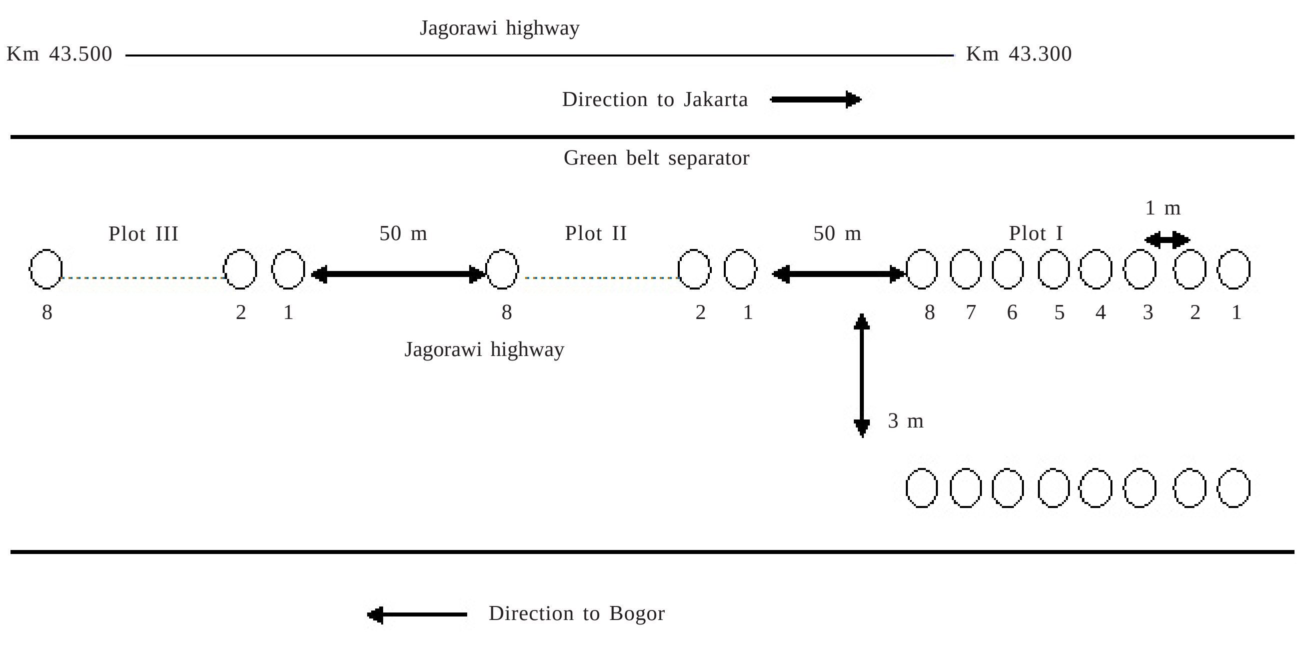

Figure 1. Experimental set up at Jagorawi highway; O 1-8: experimental pots.

C. sumatrana caused by the difficulties in measuring total leaf area in this species. Each species of plant for growth analysis was measured in three replicates.

Physiological parameters measured were total leaf ascorbate, total chlorophyll content, leaf-extract pH, and RWC. Leaf ascorbate was determined by spectrophotometer; five grams of a leaf sample was digested in metaphosphoric acid-acetic acid solution (HPO_3-CH_3COOH). The obtained extract was filtered and 0.75 g active carbon was added into 15 ml of the filtrate. A filtrate aliquot of 4 ml was placed into a reaction tube and added with mix of 10% thioureic and 1 ml dinitrofenilhidrazin as the indicator. The reaction tubes were placed in a waterbath in 37 ^oC for 3 hours, then cooled in ice and added with 85% H_2SO_4. Absorbance of the sample was determined at 540 nm (Apriyantono *et al*. 1989). Total AsA content in all species in this study were categorized into low (< 10.0 mg g^{-1}), moderately (10-20 mg g^{-1}), and high (> 20 mg g^{-1}) classes.

Total Chl was measured by extracting leaf tissues in 80% acetone. The absorbance of the Chl extract was measured at 652 nm and was calculated by Arnon's method (1949).

Leaf-extract pH was determined with pH meter. Five grams of a leaf sample was digested and added with 50 ml of deionized water, the obtained suspension was measured with a pH meter (Apriyantono *et al*. 1989).

Analysis of RWC was measured with oven method (Apriyantono *et al*. 1989). Dry weight was based on dried sample of 5 g leaf in oven at 80 ^oC for 48 h. Each of physiological parameters was determined in two replicates.

All data were analyzed with analysis of variance (ANOVA) in randomized factorial design with three replicates and the means were compared with Duncan's Multiple Range Test (DMRT) with $\alpha = 0.05$.

Plant physiological data were presented as APTI (Singh *et al*. 1991), calculated as follows:

$$APTI = \frac{AsA\,(Chl + pH) + RWC}{10}$$

AsA: ascorbate (mg g^{-1}), Chl: total chlorophyll (mg g^{-1}), pH: leaf extract pH, RWC: relative water content (%).

Scoring criteria was based on modification of Dahlan (1995) in Setiawati (2000). The RGR and APTI values at the unpolluted area were compared with those polluted area. Zero score was given if there was not significant difference among means of the two areas based on two-sample t test. Positive one (+ 1) was given if there was significant difference among means of the areas based on two-sample t test, whereas value of the polluted area was higher than that of at the unpolluted one and vice versa was given negative one (-1). Subsequently, the total score of RGR and APTI was used to classify tolerance criteria as shown at Table 2. The level of plant tolerance on the basis of the combination RGR and APTI value were compared with merely APTI method.

RESULTS

Air Quality Parameters at Jagorawi and Sindangbarang. The highest differences between polluted and unpolluted areas in the air quality parameter were showed in the SO_2 concentration. Concentration of NO_2 at Jagorawi was four times higher than that at Sindangbarang, and total particulates at Jagorawi were three times higher than those at the unpolluted area (Table 3). However, CO was found only at Jagorawi. Mean of traffic volume at Jagorawi was 2,940 $\pm$ 10 cars h^{-1}.

Plant Growth Analysis. There were no significant effects of plant species and air pollution on the plant height rate after week 14 (P = 0.65, see Figure 2). Based on total leaf area, RGR value of *L. speciosa* at the polluted area was higher than that the unpolluted one. Maximum RGR of *L. speciosa* at the polluted area (0.17) was reached at week 4 and 8, and then it declined until week 14. *Pterocarpus indicus*, *D. regia*, and *S. macrophylla* grown at the two areas had not sifnificant RGR values. Relative growth rate values of *G. arborea*, *C. burmanii*, and *M. elengi* at the polluted area was lower than the unpolluted one, and there was significantly different (Figure 3).

Table 2. Tolerance classes'criteria in the basis of relative growth rate (RGR) and air pollution tolerance index (APTI) on this study (modification of Dahlan (1995) in Setiawati (2000))

Total RGR and APTI score	Tolerance classes'criteria
-2	Sensitive (S)
-1	Intermediate tolerant (I)
0	Moderately tolerant(M)
1, 2	Tolerant (T)

Table 3. Air quality values at Jagorawi and Sindangbarang

Parameter	Jagorawi	Sindangbarang
NO_2 (ìg m^{-3})	16.21 $\pm$ 0.16	4.29 $\pm$ 0.08
NH_3 (ìg m^{-3})	34.96 $\pm$ 1.65	16.43 $\pm$ 0.00
SO_2 (ìg m^{-3})	10.08 $\pm$ 0.00	0.06 $\pm$ 0.00
H_2S (ìg m^{-3})	5.72 $\pm$ 0.71	2.74 $\pm$ 0.00
Total particulate (ìg m^{-3})	96.05 $\pm$ 1.05	33.31 $\pm$ 0.69
Pb (ppm)	0.02 $\pm$ 0.00	-
CO(ìg m^{-3})	5271.29 $\pm$ 0.00	-
O_3 (ìg m^{-3})	0.06 $\pm$ 0.00	0.03 $\pm$ 0.01

- Undetectable

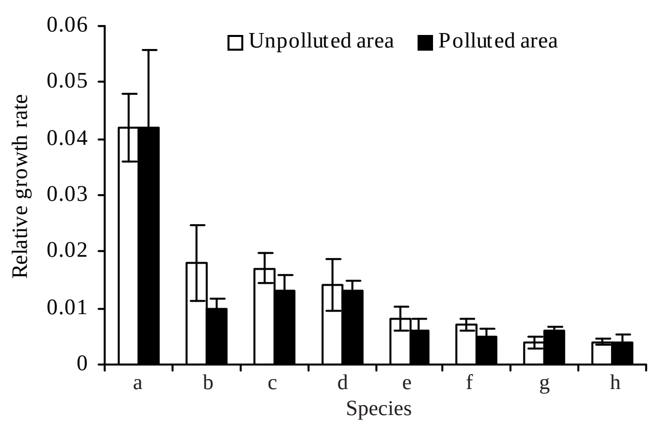

Figure 2. Relative growth rate based on plant height at unpolluted and polluted areas. a: *P. indicus*, b: *D. regia*, c: *S. macrophylla*, d: *G. arborea*, e: *L. speciosa*, f: *C. sumatrana*, g: *C. burmanii*, h: *M. elengi*.

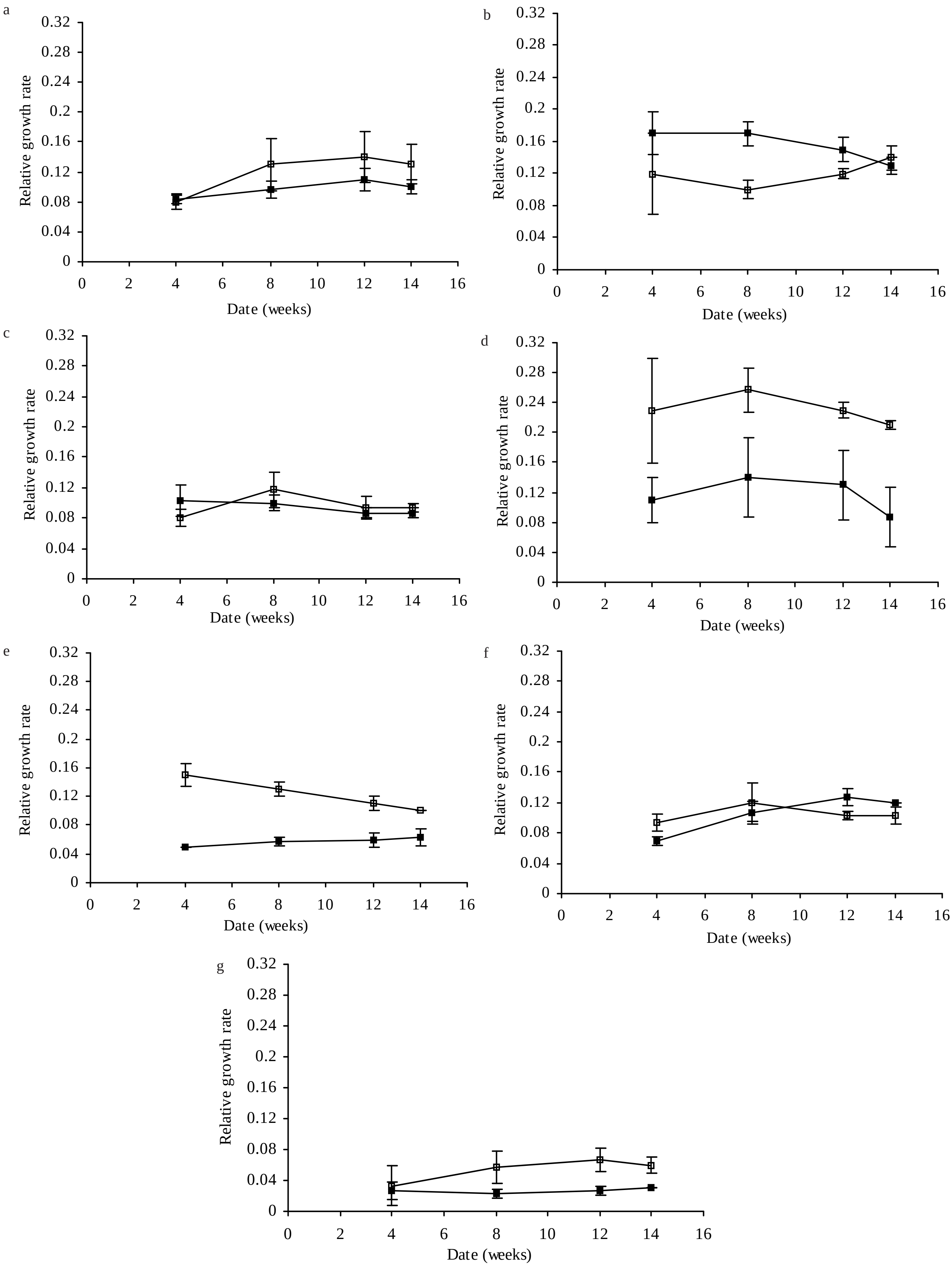

Figure 3. Relative growth rate based on the changes in leaf area of (a) *P. indicus*, (b) *L. speciosa*, (c) *D. regia*, (d) *G. arborea*, (e) *C. burmanii*, (f) *S. macrophylla*, and (g) *M. elengi* at unpolluted (U) and polluted (P) areas; □ unpolluted area, ■ polluted area

Physiological Parameter Analysis. This studied showed that AsA among two pollution condition was no significant different ($P = 0.10$) (Table 4), however based on t-test of each species, *L. speciosa* showed significant different about two pollution condition ($P < 0.01$). Total Chl was varied from 2.26 (*C. sumatrana* at polluted area) up to 4.38 mg g^{-1} (*S. macrophylla* at polluted area), however there was no significant interaction between species and pollution condition ($P = 0.33$). This study showed significant interaction between species and pollution condition at leaf-extract pH ($P < 0.01$). Leaf – extract pH of *L. speciosa*, *D. regia*, *C. burmanii*, and *S. macrophylla* at the polluted area were similarly with that at the unpolluted area, while that of *P. indicus*, *C. sumatrana*, *G. arborea*, and *M. elengi* were higher at the polluted area compare to that at the unpolluted area. Analysis of RWC showed that there was significant different among two pollution condition ($P < 0.01$), but no significant interaction between species and pollution condition ($P = 0.11$) (Table 4).

Tolerance Levels of Roadside Tree Species Based on APTI (Singh *et al.* 1991). On the basis of Singh criteria, *D. regia* was categorized as a tolerant species. *Pterocarpus indicus*, *C. sumatrana, G. arborea, C. burmanii, S. macrophylla*, and *M. elengi* were categorized as intermediate tolerant species, whereas *L. speciosa* was a sensitive species (Table 5).

Tolerance Levels of Roadside Tree Species Based on RGR and APTI. Based on the combining of RGR in this study and APTI (Singh *et al.* 1991), *L. speciosa* was categorized as a tolerant species to the air pollutants. *Pterocarpus indicus, D. regia*, and *S. macrophylla*, were categorized as moderately tolerant species. While *G. arborea*, *C. burmanii*, and *M. elengi* were categorized as intermediate tolerant species (Table 5).

DISCUSSION

Effect of Air Pollutants on RGR. Based on total leaf area, this study showed that air pollutants resulted lower plant RGR value of in *G. arborea*, *C. burmanii*, and *M. elengi*. The lower RGR under a polluted area might be due the decreasing of leaf production rate. The same result also reported by Pandey and Agrawal (1994); RGR value based on leaves number of polluted urban areas was relatively lower than those in unpolluted area. Hence, RGR can explain photosynthesis efficiency since more photosynthates allocated for leaf production (Lambers 1998). These results agreed with those reported by Furukawa (1991); i.e. SO_2, NO_2, and O_3 could inhibit net photosynthesis of *Populus euamericana* and *Helianthus annuus*. The inhibition of net photosynthesis would inhibit the assimilate translocation and eventually leaf area would decrease. This study found that the total leaf area of *L. speciosa* induced when they were grown in the polluted area. These phenomena indicated that the photosynthetic allocation was not inhibited, and an acclimatization to the pollution condition occurred. Changes in RGR suggested that there are effects of air pollutants on tree species and it was depend on the plant acclimatization and tolerance capability.

Figure 3 showed that there was variation in maximum RGR value of each species, which it explaining different plant growth capacity of each species. The time to reach maximum RGR of each species was also different indicating that each species had difference in capability of acclimatization. The maximum RGR value of *P. indicus* and *S. macrophylla* was reached at week 12. This fact illustrated that those species had better acclimatization capability than the other species which had maximum RGR values at week 8 or 4, such as

Table 4. Means of total ascorbate, chlorophyll, leaf-extract pH, and relative water content at unpolluted (U) and polluted (P) areas

Species	Total ascorbate (mg g^{-1})		Total chlorophyll (mg g^{-1})		Leaf-extract pH		Relative water content (%)	
	U	P	U	P	U	P	U	P
P. indicus	7.54a	6.62a	4.15a	4.01a	5.47bc	5.75a	69.59a*	71.29a
L. speciosa	4.03a	4.59a	2.89a	2.98a	4.27i	4.26i	54.32a	61.11a
C. sumatrana	8.70a	8.64a	2.86a	2.26a	4.14j	4.78g	67.46a	70.09a
D. regia	21.66a	19.27a	4.19a	4.05a	5.13dc	5.17de	64.07a	69.22a
G. arborea	11.09a	8.64a	3.02a	2.78a	5.42c	5.65ab	68.06a	67.04a
C. burmanii	8.46a	10.05a	2.53a	2.37a	4.85fg	4.68gh	56.45a	57.42a
S. macrophylla	7.89a	7.06a	4.24a	4.38a	5.29dc	5.45bc	61.40a	66.37a
M. elengi	13.95a	13.34a	3.42a	3.35a	4.50h	5.05ef	55.75a	55.53a

*Means followed by the same letter for each parameter indicate not significantly different (DMRT, $\alpha = 0.05$).

Table 5. Comparison between the combining of RGR-APTI at unpolluted (U) and polluted (P) areas and APTI criteria

Species	RGR			APTI				Sum of RGR and APTI
	U	P	Score	U	P	Score	APTI criteria	
*P. indicus**	0.12	0.10	0	14.21	13.59	0	I	0 (M)
*L. speciosa***	0.12	0.15	1	8.32	9.43	+1	S	+2 (T)
*C. sumatrana****	**	**	**	12.84	13.09	0	I	***
*D. regia***	0.10	0.09	0	26.59	24.69	0	T	0 (M)
*G. arborea**	0.23	0.13	-1	16.17	13.99	0	I	-1 (I)
*C. burmanii**	0.12	0.06	-1	11.88	12.83	0	I	-1 (I)
*S. macrophylla***	0.10	0.11	0	13.66	13.58	0	I	0 (M)
*M. elengi**	0.05	0.02	-1	16.62	16.76	0	I	-1 (I)

*Tolerance based on APTI citeria at *evergreen* species, sensitive (S) <12, intermediate (I) 13-16, moderately (M) 17-20, tolerant (T) >20.
**Tolerance based on APTI citeria at *deciduousn* species, sensitive (S) <14, intermediate (I) 15-19, moderately (M) 20-24, tolerant (T) >24.
***RGR was not measured caused by the difficulties in measuring total leaf area.

D. regia, G. arborea, and *C. burmanii*. The results in confirmed with a study by Pandey and Agrawal (1994) which showed that species with low capability of acclimatization reached faster maximum rate production leaf than other species with high capability. Furthermore, the similar plant height resulted from this study indicated that the air pollutant concentration at Jagorawi had not reach the phytotoxic level as yet.

In this study, three air quality parameters i.e. SO_2, NO_2, and particulate matter at polluted highway were higher than those at the unpolluted. The last two parameters were considered as the main factors affecting RGR value.

Nitrogen was the first factor which affected relative growth rate of plant. Plant acclimatization to stress condition was indicated from the vegetative plant growth which mainly requires nitrogen availability. Plants obtained most nitrogen from root absorption; but other sources in the form of NO_2 and NH_3 were captured by the leaves (Rogers & Aneja 1979; Farquhar *et al*. 1980; Ammann *et al*. 1995). This study showed that although the RGR values of *G. arborea, C. burmanii,* and *M. elengi* was lower than that the unpolluted one, there was not show visual injury. It was indicate that concentration of NO_2 (16.21 µg m^{-3}) at the highway was not in phytotoxic level. This result was confirmed with Malhotra and Khan (1984) which showed that in many controlled environment studies, air pollutants heve been shown to reduce the growth before any visible symptoms appeared. Better RGR at polluted area than the unpolluted as shown by *L. speciosa* suggested that NO_2 at Jagorawi could use for plant growth. This data was agreed with Mansfield (2002) which showed that NO_2 at very low doses can stimulate plant growth. Jensen and Pilegaard (1993) showing that the absorption of NO_2 from polluted air contributed 5-6% of total N needed.

The high particulate concentration at Jagorawi (96.05µg m^{-3}) was the other air quality parameter which might affect plant growth. At the polluted area, RGR values of *G. arborea*, *C. burmanii,* and *M. elengi* lower than at the unpolluted area. It might be as a response to the deposition of particulate on foliar surfaces. The deposition of particulate could inhibit gas exchange through stomata thus consequently affect the photosynthesis (Larcher 1995). This result was in congruence with Singh (1980) that combining effect of NO_2 and cement dust caused reduction in chlorophyll and biomass accumulation. Armburst (1986) also showed that dust deposit on leaves reduces photosynthesis on cotton plant.

The concentration of SO_2 at Jagorawi (10.08 µg m^{-3} ~0.004 ppm) was suggested as low doses. Sulphur was absorbsed by plant mainly as SO_4^{2-} ion as stated by Gardner *et al.* (1991) and also as SO_2 (Pfanz *et al.* 1987). The response of all species due to the concentration of SO_2 at Jagorawi were variated. This study showed that RGR value of *L. speciosa* at the polluted area was higher than at the unpolluted. This result with confirmed with Malhotra and Khan (1984) showed that exposure to low SO_2 concentration generally stimulates photosynthesis. In the contrary, the RGR values of *G. arborea, C. burmanii,* and *M. elengi* at the polluted area was lower than the unpolluted one. This fact indicated that these species was sensitive due to SO_2 concentration at Jagorawi. This result congruence with Ashenden and Mansfield (1977) which showed exposure of 0.11 ppm SO_2 significantly reduced the growth of *Lolium perenne* (ryegrass).

Physiological Responses of Plants. The exposure of SO_2 and NO_2 could decrease leaf extract pH as stated by Larcher (1995). Leaf-extract pH content of all species was varied in response to pollution condition showing significant interaction value ($P < 0.01$). The leaf-extract pH of *P. indicus, C. sumatrana, G. arborea,* and *M. elengi* at the polluted area were higher than the unpolluted one, and not for the others. The changes in leaf-extract pH might influence the stomata sensitivity due to air pollutants. The plants with high sensitivity to SO_2 and NO_2 closed the stomata faster when the exposed to the pollutants (Larcher 1995). Consequently, sensitive plants had higher leaf-extract pH than tolerant plants

The changes in AsA content in each species was varied from 0.06 up to 2.39 mg g^{-1}, but there was no significant difference ($P = 0.10$) among two pollution condition. This study was confirmed with Pandey and Agrawal (1994) which showed that AsA content of plant species at urban polluted area was no different with that at the unpolluted area.

The study also showed that there was no significant difference among two pollution condition to total Chl content ($P = 0.07$). It was disagreed with Pandey and Agrawal (1994) result which reported content chlorophyll plants at urban polluted was lower than the unpolluted area. The different result caused by the difference in air pollutant concentration at those studies. Mean concentration of SO_2 and NO_2 at the urban polluted were 50.50 and 45.19 µg m^{-3}, respectively. Concentration of SO_2 (10.08 µg m^{-3}) and NO_2 (16.21 µg m^{-3}) at the highway has not reach the phytotoxic level, hence did not affect the Chl content.

Relative water content expressed the balance of plant water uptake and release (Jones 1994). This study showed that RWC of two pollution condition was no significant difference ($P < 0.10$). This result explained that air pollutant concentration did not affect to RWC of those plant at the polluted area. This means that air pollutant at Jagorawi has not disturbed the water balance of plant yet. This result indicated that plant with sufficient water content, still can expand the total leaf area as stated by Schuppler *et al.* (1998).

Tolerance Levels Based on RGR and APTI. This study showed that RGR and APTI of *L. speciosa* at the polluted area were higher than that at the unpolluted area, and total score of the two parameters was 1. Thus, *L. speciosa* was categorized as a tolerant species. This result was opposite to result based on merely APTI criteria which categorizing *L. speciosa* as a sensitive species. In APTI formulation, total ascorbate was the most important properties, consequently plant with low ascorbate such as *L. speciosa* would had low APTI value and was categorized as sensitive species.

Both based on merely APTI value and combining of RGR and APTI, *G. arborea* and *C. burmanii* were categorized as intermediate tolerant species. Relative growth rate of *G. arborea* and *C. burmanii* at the polluted area was lower than that at the unpolluted one. The APTI value of *G. arborea* and

C. burmanii at the polluted area lower than that at the unpolluted one, while there was no significant effect of pollution to APTI values. This fact indicated that air pollutant affected physiological processes in those species and subsequently reduced the RGRs.

Based on RGR and APTI value, *P. indicus, D. regia, S. macrophylla,* and *M.elengi* were categorized as moderately tolerant species. This result was similar with tolerance level based on merely APTI value which categorized those species as intermediate tolerant species.

In the combination of RGR and APTI method, values of RGR and APTI were of similarly importance. Continuity of the changing in physiological parameters was showed at RGR value. If value of RGR increases, it illustrate that plant species is able to eliminate the disturbing effect of air pollutant, and vice versa. Thus, the determination tolerance levels of plant species by combining RGR and APTI values more accurate than that of APTI value only.

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