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IMPACT OF AIR POLLUTION OF VEGETATIVE GROWTH (*GUAIACUM OFFICINALE*) IN KARACHI

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Data on ecological parameters like leaf area, its dry matter, senescence, flowering and fruiting of *Guaiacum officinale* have been recorded for two years to quantify the impact of air pollution due to vehicular exhaust emissions at 20 traffic congestion points in Karachi. It has been found that the Grumandir site is seriously affected with respect to leaf area, dry weight and senescence while at Nazimabad and Tariq Road the impact is high with regard to flowering and fruiting. The plants at Karachi University are least affected. There is a 40% reduction in leaf area at highly polluted spots. The dry weight of the leaves is more sensitive to pollution and is noted to decrease with increase in the degree of pollution. Flowering of elder plants at the polluted sites spanned over 5 to 6 months, while at the least polluted spots they did not do so only in January and February. Also at the former spots the falling of leaves had since been completed in the third week of February when the process had just started at the latter station. The observed impact of air pollution seems to suggest a relation with early aging of plants. The observed stunted growth is suggested to be due to reduction in cell wall extensibility and for reducing the degree of hydration and early maturity of the leaves. The dehydration conditions created by the hydrophobic macro-environment of the pollutants alter the micro-environment of the plants and lead to the so called invisible injury or early aging.

Key words: Air pollution, Vegetative growth, *Guaiacum officinale*, Aging, Micro-environment.

INTRODUCTION

The city of Karachi is faced with a serious exhaust emission hazard from vehicular traffic [1]. The smoke and unburnt fuel discharged from rickshaws and faulty automobiles have polluted the air to such an extent that the deposited particulate matter has changed the colour of tree leaves from green to grey. Plant growth has been adversely affected at traffic congestion points in the city areas. This paper describes the impact of air pollution on plants, particularly *Guaiacum officinale* planted on roadsides of the city for its beautification.

Plants adapt to a particular composition of the three major determinants of environment *viz.* soil, water and air. When the critical limits of adaptation and tolerance are exceeded, a stress situation is created and the sensitive components of the system start malfunctioning. The impact of air pollution on plants is accordingly observed as alteration of some of the metabolic processes.

Extensive studies have been carried out to quantify the effects of different gaseous pollutants on plants. Mudd and Kozlowski [2] have recorded a number of studies in which plants were exposed to one or a mixture of gases maintaining their proportion in a controlled environment throughout the experiment. It was, for example, noted that stomatal resistance increased in response to a mixture of SO_2 and O_3 than under either SO_2 or O_3 exposure. The stomatal physiology is affected differently by pollutant mixtures compared to that by pollutants [3]. At roadside the plants are exposed to a mixture of several gases including unburnt hydrocarbons and they experience fluctuation in their composition due to wind and local air turbulance caused by speeding vehicles. The polluted spots experience instantaneous changes in the composition of the air with the passage of vehicles since their rapid movement draws in fresh or less polluted air from the immediate environment (Beg and Shams, unpublished data). An interesting experiment by Wellburn [4] shows that exposure of *Vicia faba* to low concentration of SO_2 imparts swelling of the fretmembrane of the chloroplasts. This swelling was found reversible when exposed to the pollutants for one hour, followed by exposure to the unpolluted air.

MATERIALS AND METHODS

Twenty stations were selected for the study of the impact of air pollution on *Guaiacum officinale* (Fig. 1). These included 16 stations where the plants were growing on road islands, (2) on roadside (Shahrah-e-Quaidin) and (3) on lawns (Karachi University, Quaid's Tomb 1,2). The plants were divided into two age groups: less than 8 years and more than 8 years.

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Data on leaf character viz. leaf area, leaf dry weight, leaf senescence, and on reproductive phenology viz. flowering and fruiting were recorded throughout the years 1986 and 1987. The area and dry weight of ten leaves, each from three different trees were measured once a month. The leaf area was measured by using a graph paper and the dry weight of leaves was obtained by oven-drying at 65° for 8 hours. The dry weight per square centimeter of leaves was then calculated. The flowering and fruiting of the plants were recorded on the 5th, 15th and 25th day of each month. For flowering and fruiting eight trees were taken with the exception of areas where the plants were not as many.

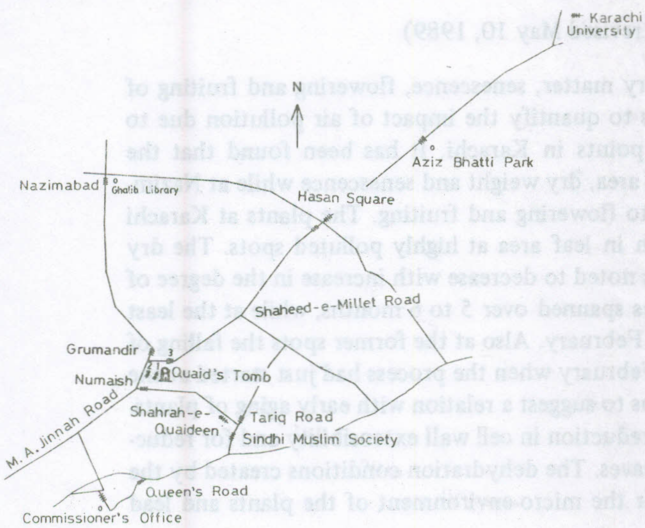


Fig. 1. Map showing study sites on Karachi roads.

The number of + signs in the Figs. indicates the intensity of flowering and fruiting. The senescence of leaves was studied from 27 January, 1987 to 4 April, 1987. Eight twigs of almost the same size were plucked from different parts of the plants each from three different trees. The number of old and new leaves were counted to determine the ratio of leaf senescence and leaf emergence. The data were analysed using analysis of variance techniques.

RESULTS

The results of survey indicate that the impact of air pollution is heavy on plants growing on the roadside as compared with those planted at the university and at sites 1 and 3 of the Quaid's Tomb. Plants at different sites respond differently to air pollution as is evident from (Fig. 1-8).

Significant difference ($P < 0.01$) among the leaf characters of plants growing at different localities of Karachi was found.

On the basis of leaf area, leaf dry weight and leaf senescence, plants growing at Grumandir are the worst affected. On the other hand the flowering and fruiting pattern shows that plants growing at Nazimabad are seriously affected. The plants growing at Karachi University appear to be least affected if at all by air pollution. However, on the basis of the fruiting pattern plants growing at Commissioner's office were even less affected than those at Karachi University.

Tariq Road does not experience as high a traffic volume as Grumandir and Nazimabad, but the plants growing at this site are also among those seriously affected since the flowering pattern is in no way better than that at Grumandir or Nazimabad. This is perhaps because its road-island is narrower compared with that of the other study sites. A very short distance is consequently left between the vehicles passing from opposite directions and the plants. Such a situation results in higher gaseous exposure compared with plants growing at the roadside of Shahrah-e-Quaidin and Commissioner's office where they are planted approximately 5 metres away from the road. With the exception of leaf senescence, other parameters at the latter two sites show almost the same results as the plants growing at Karachi University and Quaid's Tomb.

A 40 % reduction in leaf area was measured for the plants growing in highly polluted spots compared with those growing in the unpolluted spots, (Fig. 2). The leaf area increased with a decrease in pollution. Differences between the leaf area of plants of different age groups were not marked. The impact of pollution is apparent more from the dry weight of leaves than from leaf area. The dry weight of the leaves of plants growing in the highly polluted spots is reduced more than those growing in less polluted areas (Fig. 3). The dry weight per unit area of leaves was higher in unpolluted as compared with the polluted spots (Fig. 4).

The younger (< 8 years) plants growing in the polluted spots viz. M.A. Jinnah Road, Nazimabad, Hasan Square and NIPA did not flower (Fig. 5) while the younger as well as elder plants (> 8 years) flowered equally well and almost throughout the year in other polluted areas (Figs. 5,6). In the highly polluted spots the flowering of elder plants spanned only over a period of 5 to 6 months (Fig. 5). At Karachi University, the elder plants did not flower in February while the younger ones did not do so in both January and February. At Nazimabad, the most affected spot according to the flowering pattern of plants, not a single flower was noted on the plants from 5th December to 15th June. Since the younger plants growing at the polluted spots did not show flowering, they, as a natural consequence, did not bear any fruit (Fig. 8). The plants of both age groups growing in the unpolluted areas, on the other hand continued to show flowering and fruiting throughout the year (Figs. 5-8). Intensive fruiting was noted on the plants growing at Commissioner's office whereas in the highly polluted spots only a few fruits on

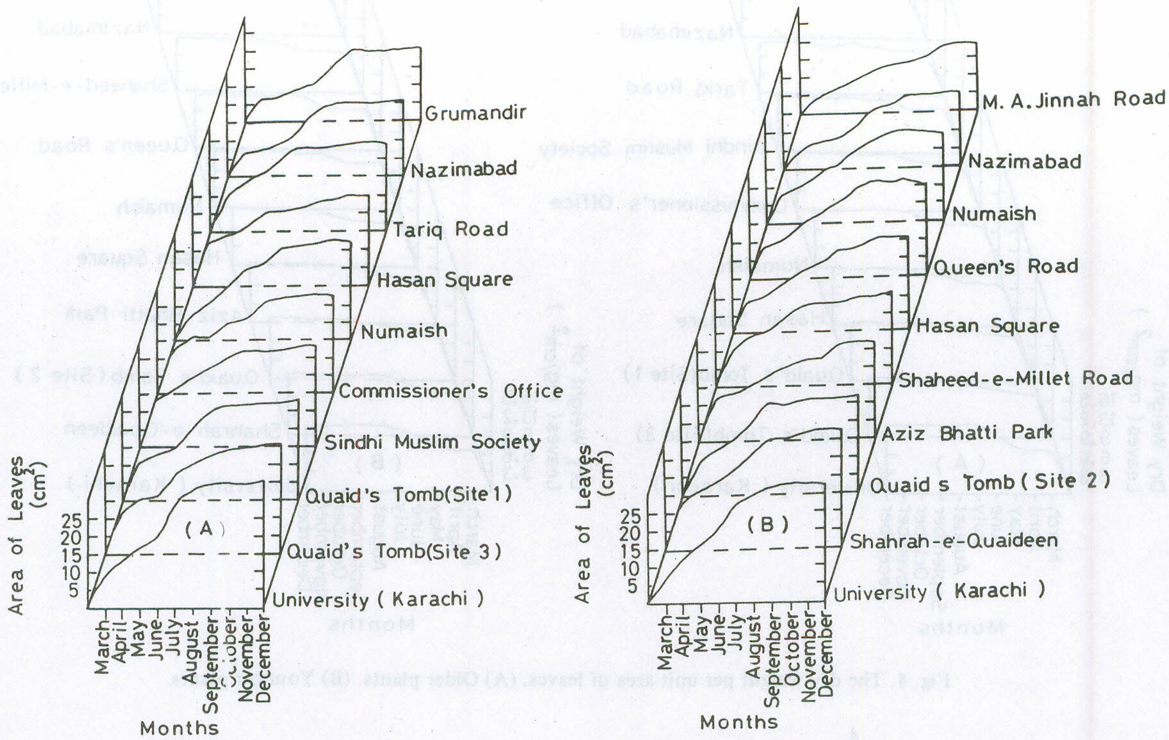


Fig. 2. The area of leaves collected from different region of Karacni. (A) Older plants. (B) Younger plants.

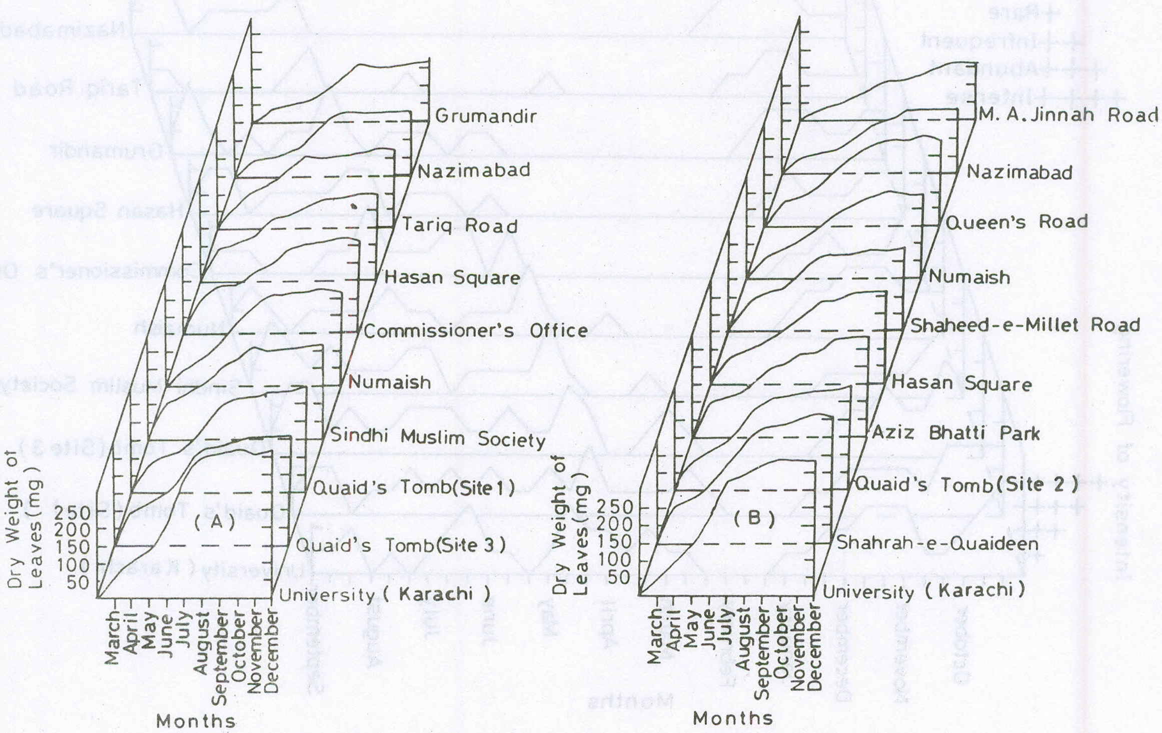


Fig. 3. The dry weight of leaves collected from different areas of Karachi. (A) Older plants. (B) Younger plants.

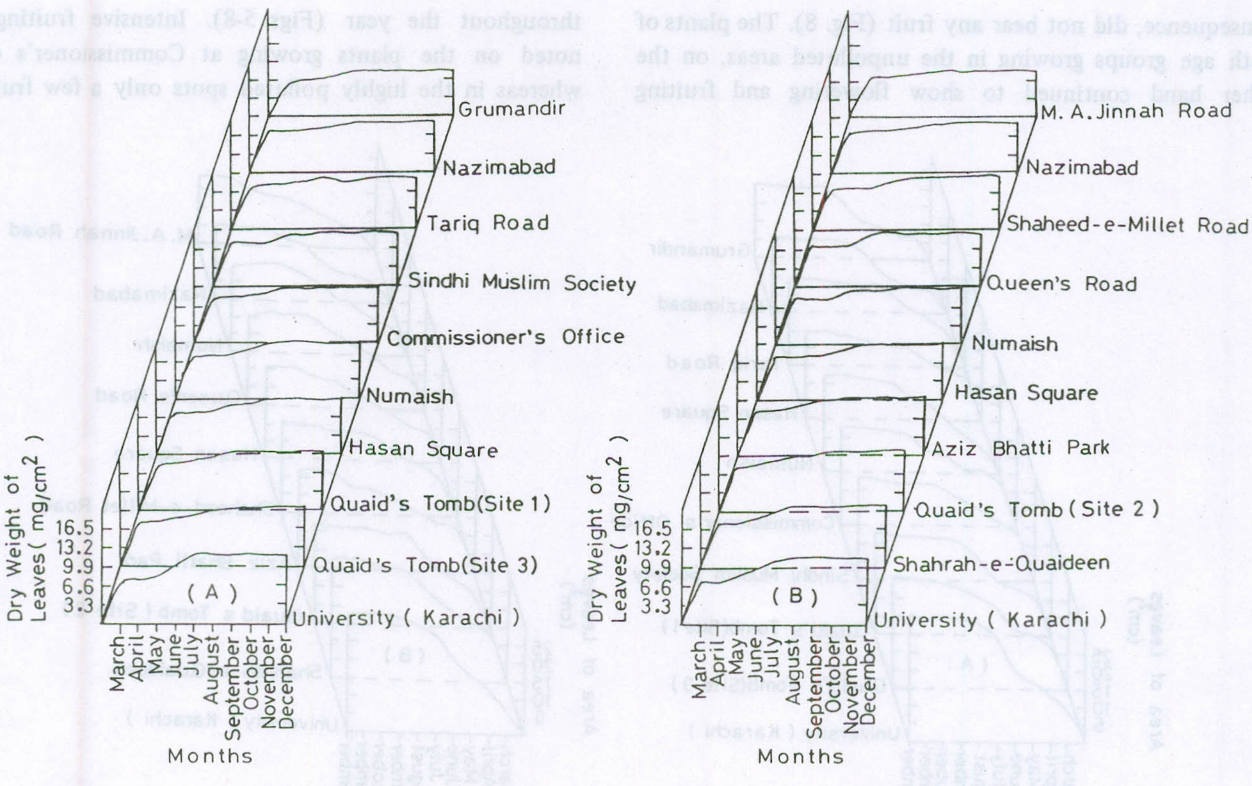


Fig. 4. The dry weight per unit area of leaves. (A) Older plants. (B) Younger plants.

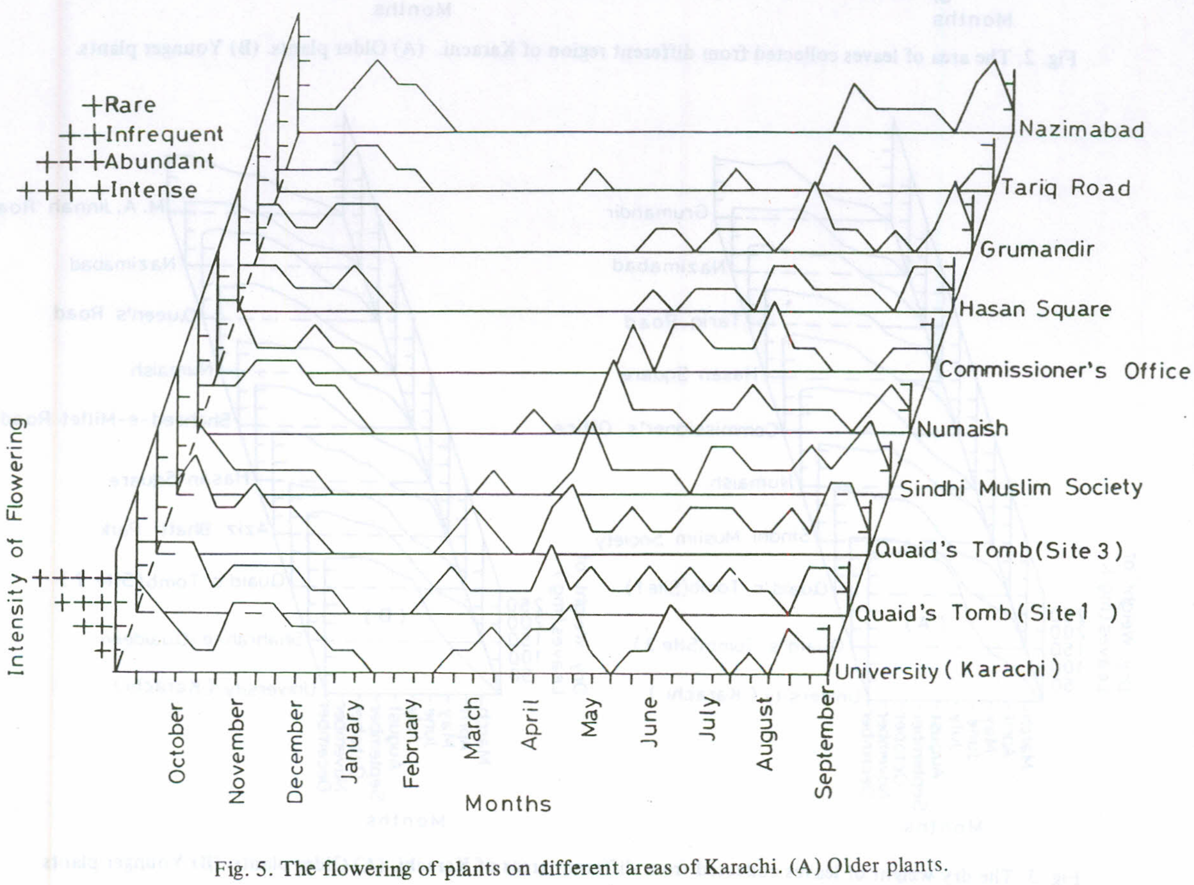


Fig. 5. The flowering of plants on different areas of Karachi. (A) Older plants.

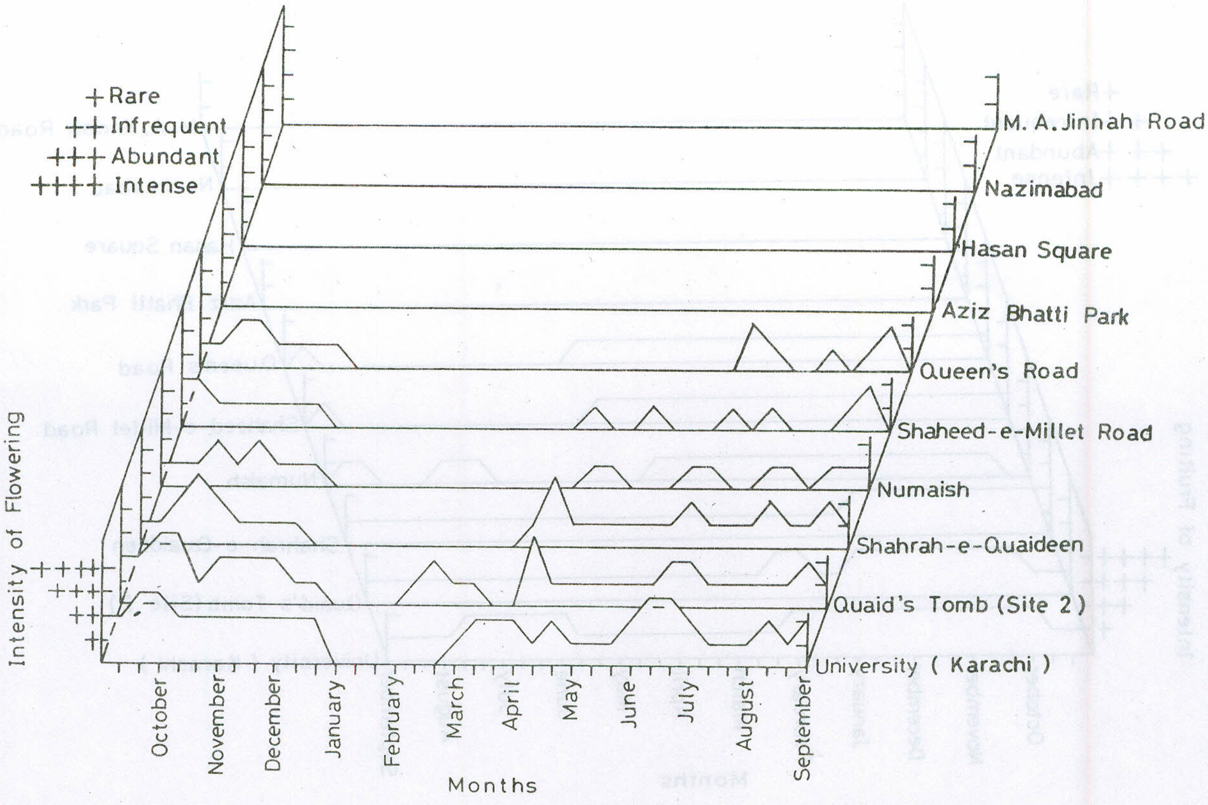


Fig. 6. The flowering of plants on different areas of Karachi. (B) Younger plants.

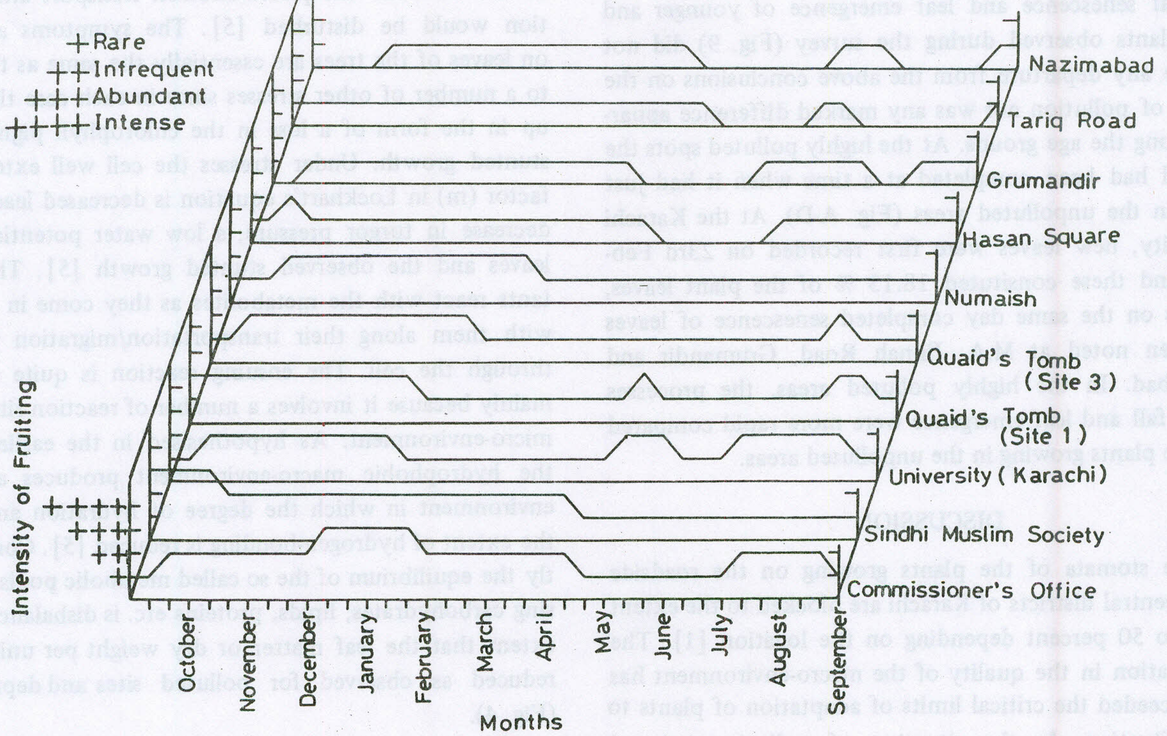
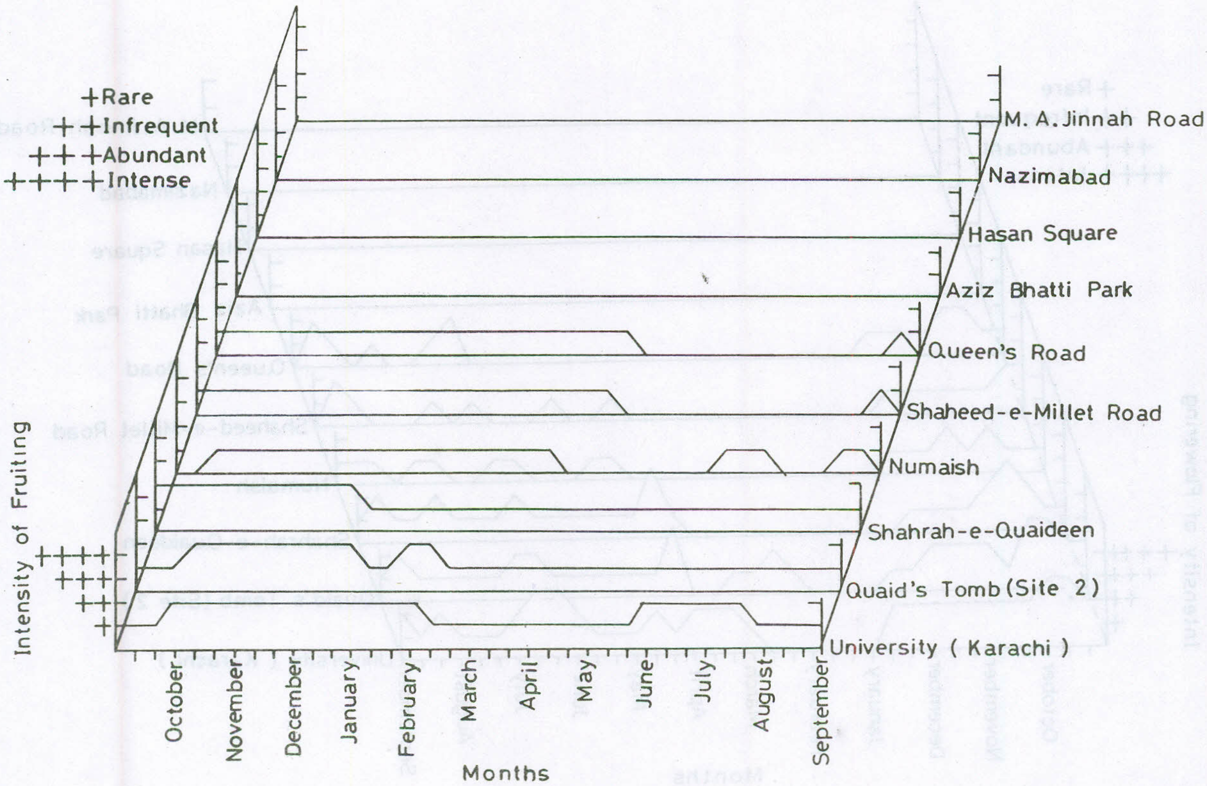


Fig. 7. The fruting of plants on different areas of Karachi. (A) Older plants.



•Fig. 8. The fruiting of plants on different areas of Karachi. (B) Younger plants.

the plants were noted (Fig. 7-8).

Leaf senescence and leaf emergence of younger and elder plants observed during the survey (Fig. 9) did not indicate any departure from the above conclusions on the impact of pollution nor was any marked difference apparent among the age groups. At the highly polluted spots the leaf fall had been completed at a time when it had just begun in the unpolluted areas (Fig. A-D). At the Karachi University, new leaves were first recorded on 23rd February and these consituted 18.13 % of the plant leaves, whereas on the same day completed senescence of leaves had been noted at M.A. Jinnah Road, Grumandir and Nazimabad. In the highly polluted areas, the processes of leaf fall and leaf emergence were more rapid compared with the plants growing in the unpolluted areas.

DISCUSSION

The stomata of the plants growing on the roadside of the central districts of Karachi are blocked to the extent of 20 to 50 percent depending on the location [1]. The deterioration in the quality of the macro-environment has thus exceeded the critical limits of adaptation of plants to stress situation. In the situation of pollution induced deterioration of the micro-environment at the guard cells, the cellular pH as well as membrane permeability should be altered while the photo-electron transport and respiration would be disturbed [5]. The symptoms appearing on leaves of the trees are essentially the same as those due to a number of other stresses since in each case they show up in the form of a loss in the chlorophyll pigment and stunted growth. Under stresses the cell well extensibility factor (m) in Lockhart's equation is decreased leading to a decrease in turgor pressure, a low water potential in the leaves and the observed stunted growth [5]. The pollutants react with the metabolites as they come in contact with them along their transportation/migration pathway through the cell. The ensuing reaction is quite complex mainly because it involves a number of reaction sites in the micro-environment. As hypothesised in the earlier paper, the hydrophobic macro-environment produces a micro-environment in which the degree of hydration and hence the extent of hydrogen-bonding is reduced [5]. Consequently the equilibrium of the so called metabolic pools comprising carbohydrates, lipids, proteins etc. is disbalanced to an extent that the leaf matter or dry weight per unit area is reduced as observed for polluted sites and depicted in (Fig. 4).

The plants growing in the polluted spots did not show foliar lessions such as necrosis and/or chlorosis except that

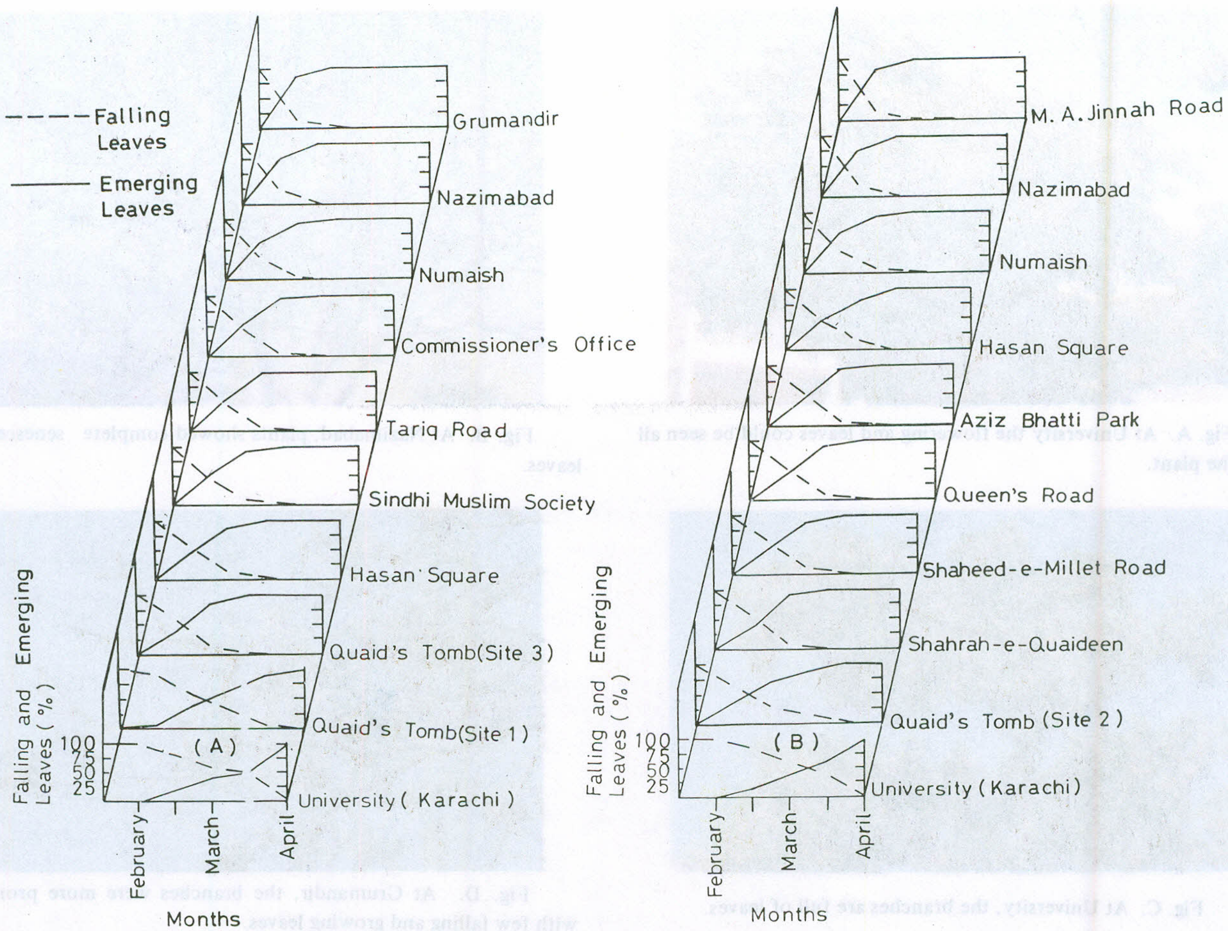


Fig. 9. The proportion of leaf falling and leaf generation. (A) Older plants. (B) Younger plants.

the colour of the leaves was dark or greyish green whereas the foliar parts of the plants growing in unpolluted spots were light green in colour. A number of workers [7-13] have defined the injury which was not accompanied by foliar lessions as hidden damage or invisible injury. Working with hydrogen fluoride Thomas and Hendricks [13] defined invisible injury in terms of reduction in photosynthesis and accordingly it appears that the plants growing in the polluted spots of Karachi have suffered invisible injury. The same authors [13] suggest that invisible injury occurs (1) only when a threshold concentration is exceeded and (2) with a certain magnitude and for a limited duration starting from the initiation of exposure to pollutants to its cessation. Although the plants growing in the polluted spots are exposed to high concentration of air pollutants, almost every minute during peak traffic hours, the polluted spots experience a gush of fresh or less polluted air due to turbulence created by the moving/rushing vehicles.

The impact of air pollution on plants is quite complex since a mixture of pollutants is involved. The interactive effects may be antagonistic, additive or synergistic [14]. The present study indicates that a combination of these interactive effects have had a serious impact on the growth of the plants species under consideration. These effects have surfaced up in the form of (1) reduction in yield, (2) alteration in individual physiological, and biochemical processes and (3) disturbance in the micro-environment of plants so that the activities such as stomatal function, photosynthesis, gas exchange, water balance and enzymic functions have been altered [5].

Further support to the above observations and hypothesis are provided by an increase in the concentration of CO_2 induced stomatal closure. Absicic acid (ABA) is also known to exhibit similar reaction, and has the ability to control CO_2 induced stomatal closure [15]. Changes in ABA are therefore indicated by the plant sensitivity. Protection is provided by high CO_2 concentrations against SO_2+NO_2 induced injury [16]. 0.08 ppm SO_2 increased the foliar injury caused by CdO, PbO, CuO and MnO dusts to lettuce *Lactuca sativa* L [17].

Fig. A. At University the flowering and leaves could be seen all over the plant.

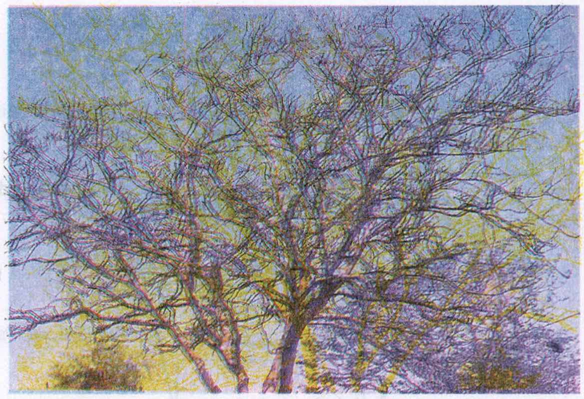


Fig. B. At Nazimabad, plants showed complete senescence of leaves.

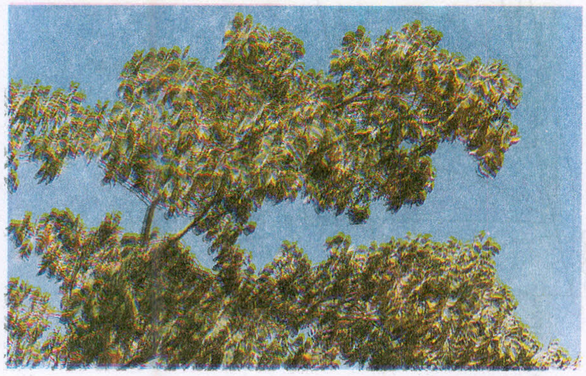


Fig. C. At University, the branches are full of leaves.

Fig. D. At Grumandir, the branches were more prominant, with few falling and growing leaves.

Fig. E. At Quaid's Tomb site 3, the tree crown was rounded.

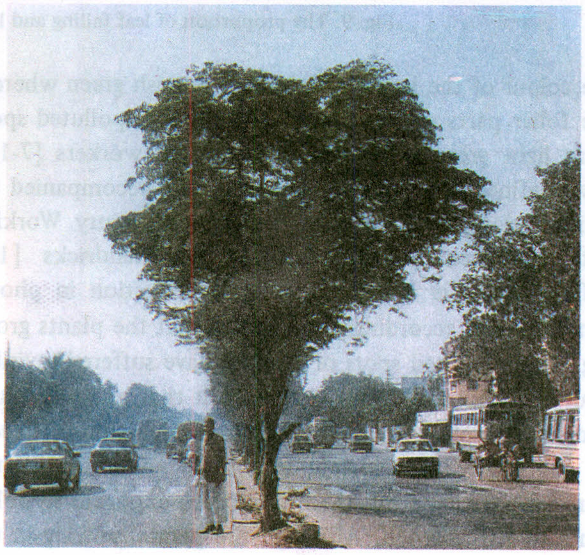


Fig. F. At Grumandir, the tree crown was V-shaped.

Antagonizing effects of gases which inflict invisible injury to plants may be marked. Such effects have, for instance, been noted in the case of sulphur dioxide and nitrogen dioxide which separately increased the growth of *Trifolium repens* but in combination SO_2 greatly reduced the beneficial effects of NO_2 [18]. When *Citrus nobilis*, was fumigated with a mixture of sulphur dioxide and hydrogen fluoride [19] and *Avena sativa* with SO_2 and

NO_2 [20] antagonastic effects were noted.

It appears that the reduction in cell wall extensibility is the basis for reduction in the degree of hydration and early maturity so that aging and the reversal of growth processes set in. The dehydration conditions due to the hydrophobic macro-environment created by pollutants like unburnt hydrocarbons and the mixture of other toxic gases emitted by vehicular traffic alter the micro-environment of the leaves of the plants growing in the polluted spots in Karachi. The attachement of leaves with the branches of plants growing in the polluted area is for the same reason weaker than those growing in the unpolluted spots. The above effect was quite noticeable at Grumandir, M.A. Jinnah Road and Nazimabad. In the present study the lower branches of the plants were damaged to a higher degree as compared with the upper branches (Fig. F). Bleasdale [21] showed that the aerial parts of the plants particularly the leaves were adversely affected by smoke pollution whose level, during the last 14 years in Karachi, has increased by about 5 times [22]. This suggests that the hydrophobic and toxic macro-environment is more dominant at lower levels than at higher ones, possibly because the latter can get fresh air due to turbulance created by speeding vehicles.

Exposure to air pollution has substantially inhibited the flowering of younger plants and this has resulted in the loss of their flowering and fruiting. The flowering of older plants growing in the polluted areas, spanned over only 5 to 6 months. In the unpolluted areas on the other hand flowering was observed almost throughout the year. The fruiting of older plants growing in the polluted spots was not much affected by air pollutants if it was compared with flowering at unpolluted spots. At some polluted spots, for instance, Commissioner's Office and Sindhi Muslim Society, it showed lesser impact, which indicates that the pollination and fertilization were not much affected at these places.

The senescence of the leaves of plants growing in the highly polluted areas took place 1½ months earlier than those growing in the unpolluted areas. A number of workers [23-25] have reported that ethylene accelerates or induces many senescence phenomena. Although it is produced endogenously by the plants [26] and functions as a growth hormone, it is an important air pollutant [27]. When tobacco was treated with ethylene, Valdovinos *et al.* [28] found disorganization of cytoplasm and the degradation of cell walls. There was an accumulation of rough endoplasmic reticulum in the cells of abscission zone of the plants and correlated it with the increase in RNA and proteins in the abscission zone after treatment with ethylene. This was also observed by Sacher [23] who suggested that this increase is related to the production of degradative enzymes involved in senescence. Matsushima and Hirada [29] observed leaf fall in citrus trees with increase in SO_2 concentration without visible injury. When soybean leaves were fumigated with hydrogen floride Wei and Miller [30] observed that it was a disruption and vesiculation of tonoplasts which may have caused the continued disintergration of the cytoplasmic organelles and cell organization. This was supported by a number of observations [31,32]. Alteration and disruption of the tonoplast membrane plays a key role in senescence leading to the deterioration and death of the cell. Accordingly it is possible that the complex mixture of air pollutants which has been suggested above to have altered the micro-environment is also responsible for the increase in the production of degradative enzymes involved in senescence and hence in the early initiation of the process in the highly polluted spots.

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