MINIMIZATION OF PHOTOSYNTHESIS DUE TO AIR POLLUTION

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Summary

In this work the leaf structure of *Phlomis fruticosa* and *Urginea maritima* from a strongly perturbated, by means of air pollution, phryganic ecosystem in Attica (Greece) was studied in comparison to the leaf structure of the same plants from a similar phryganic ecosystem free of air pollutants. The first, light microscope detected, detrimental effects of air pollutants refer to chloroplasts. The latter are fewer and smaller in the leaves of the affected plants. A second effect of air pollution on the *P. fruticosa* leaves is the shape of the chloroplast containing mesophyll cells, which appear to be more irregular than in normal plants. Besides, leaves of *U. maritima* exhibit colorless areas, that is areas without chloroplasts, where the mesophyll cell layers have been practically reduced. In other words the leaf of *U. maritima* shows abundant colorless constricted areas in its blade. It is reasonable to presume that the above effects on chloroplasts leads to the minimization of photosynthesis. Therefore, our results justify the low primary production of the most air polluted ecosystems as well as the lower biomass estimations in these, available in the literature.

1. INTRODUCTION

It seems that the basic effect of air pollution to the plants is directed towards the minimization of their productivity (1,2,4,7,8,9).

Morphological, macroscopically visible symptoms are the ultimate results of changes in the plants due to air pollution. Chlorosis of leaf tissue and breakdown of chlorophylls and other plant pigments are some of these symptoms (6).

During the last year our group started working on the effects of air pollution on Attican natural ecosystems. Our first results showed a serious decrease of plant biomass and elimination of species diversity (3). At the same time, the general appearance of the dominant plants occurring in the most polluted study areas showed an obvious perturbation and loss of vigour.

Having in mind the above, we selected two typical mediterranean plants, one geophyte (*Urginea maritima*) and a subshrub (*Phlomis fruticosa*) in order to find out the exact action of air pollution on leaf structure.

2. MATERIALS AND METHODS

The selection of the two study sites was based on the information available to us, concerning the biomass yield (3) as well as on our empirical estimation of industrial emissions. These sites are Korydalos and Varkiza. Korydalos found on a slope of Egaleo mountain facing Piraeus, is a smog-covered area, with low biomass, therefore it is considered to be a strongly

perturbated area. Varkiza, located on a southern slope of Hymettus mountain, east of Athens, is considered a non-air-polluted area, yielding to normal levels of biomass.

Leaves from *Phlomis fruticosa* and *Urginea maritima* individuals were collected keeping in mind that the plants had to be of similar phenology and their leaves had to be of the same age (Figures 1,6 and 11,18 asterisk). Micrographs presented here are coming from the same areas of the leaf blade correspondingly. Therefore, histological differences do not reflect the examination of different sites of the leaves.

Plant material was fixed in 6% glutaraldehyde in 0.025M phosphate buffer at pH 7 at room temperature for 3 hours. Postfixation was carried out in 1% OsO_4 in the same buffer. The plant material was washed in buffer and dehydrated in a gradient of aceton solution. Then it was placed in propylene oxide for 30 minutes and embedded in Durcupan ACM (Fluka). The sections (1-3 μm thick) were stained in 1% toluidine blue O in 1% borax solution according to Pickett-Heaps (5) and observed with a Zeiss light microscope.

3. RESULTS AND DISCUSSION

The leaves of *Phlomis fruticosa* (Figure 1) as they are seen in cross section are typically bifacial (Figure 2). Abundant multicellular hairs cover both the upper and the lower epidermis (Figure 2). Upper epidermis consists of one layer of flattened cells with moderately thick external wall. Lower epidermis comprises smaller thin-walled cells of irregular shape (Figure 3). Stomata occur in the lower surface of the leaf only and they are characteristically raised above the rest epidermal cells surface (Figure 3). One layer of long palisade and three to four layers of small and nearly isodiametric spongy parenchyma cells form the ground tissue of the leaves (Figure 3). Abundant large and lens-shaped chloroplasts are present in both the palisade (Figure 4, arrows) and the spongy parenchyma cells (Figure 5, arrows).

The leaves of *P. fruticosa* from the smog suffering system exhibit several green-yellow areas (Figure 6). As it is seen in cross sections, the leaf structure remains unchanged in respect of the number of cell layers of each tissue, i.e. of the epidermis (cf. Figure 7 with Figure 2), of the palisade (cf. Figure 8 with Figure 3) and spongy parenchyma (cf. Figure 10 with Figure 5). On the other hand disturbance is evident firstly in the shape of all kinds of cells of dermal and ground tissues (cf. Figures 8,9, 10 with 3,4,5, respectively) and secondly in the number, the shape and size of chloroplasts. It is evident that the number of chloroplasts is strongly eliminated in palisade (cf. Figure 9 with Figure 4) and in spongy mesophyll cells (cf. Figure 10 with Figure 5). Moreover the chloroplasts of the air-pollution affected plants are smaller and seem to be more flattened than the ones of non-perturbated plants (cf. Figures 9,10 with 4,5 respectively).

The leaves of *Urginea maritima* (Figure 11) are almost unifacial (Figure 12). The thickness of the blade is unique (Figure 12), except of the central vein and the marginal zone; the about 10 cell layered mesophyll comprises two or three layers of cells containing chloroplasts at each side (Figure 12). Abaxial chlorenchyma shows larger intercellular spaces and more irregular shaped cells (Figure 14) than the adaxial one (Figure 13).

Leaves of most plants of the air polluted area exhibit abundant pale areas on their surfaces (Figure 18). As seen in cross sectioned leaves, these areas consist of the upper and lower epidermal layers while mesophyll layers have been practically reduced from 10 (Figure 12) to 2-3 cell layers (Figure 15, open arrow-heads).

In distal areas from the narrow zone (Figure 15, upper area in the left) chloroplasts of chlorenchyma cells (Figure 16) seem to be the same in number and shape with the ones of undisturbed plants (Figure 16, cf. with Figures 12,14). Closer to the restriction (Figure 15, upper area in the middle) chloroplasts seem to be fewer and smaller (Figure 17, cf. with Figure 16 and Figures 13,14) whole parenchyma cells of the narrow areas do not contain chloroplasts (Figure 15).

The above data show clearly that the two plants, selected as indices from the perturbated area, appear considerable elimination of photosynthesis, because of the pollution-affected leaf structure. This fact undoubtedly leads the system to low productivity and degradation.

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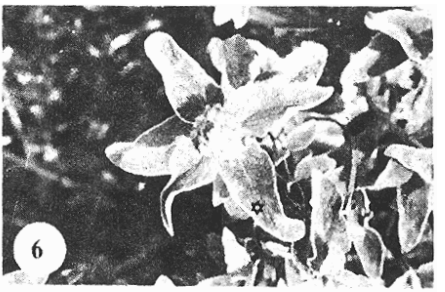
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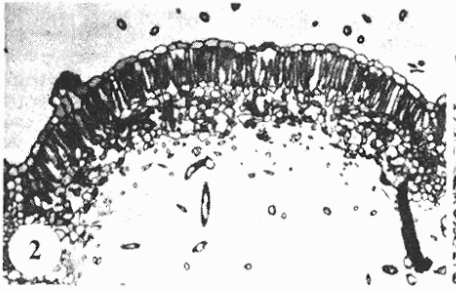
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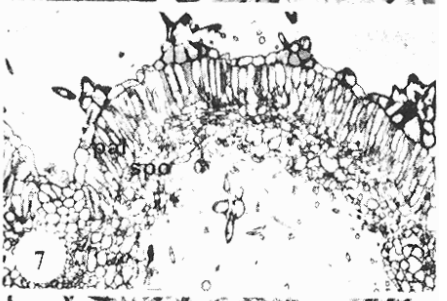
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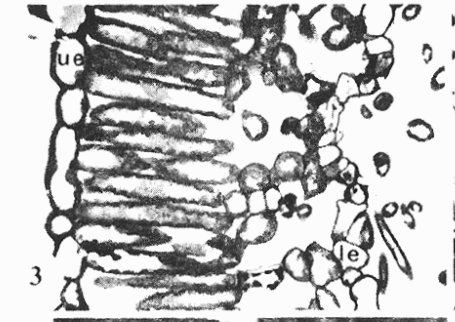
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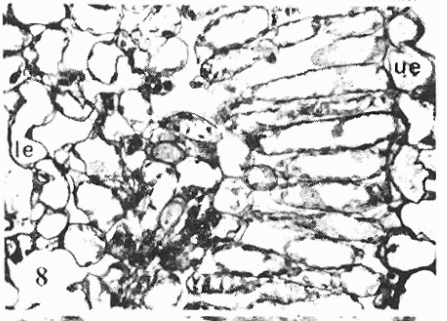
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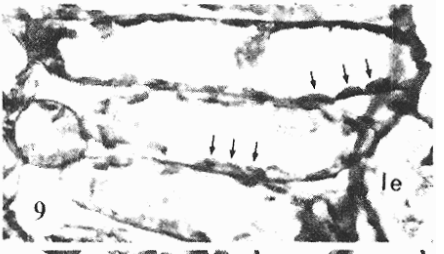
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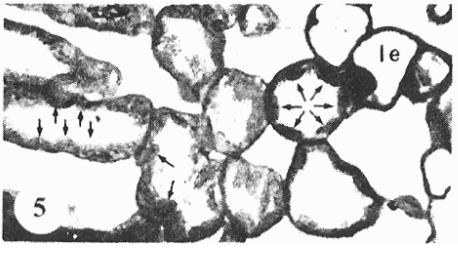
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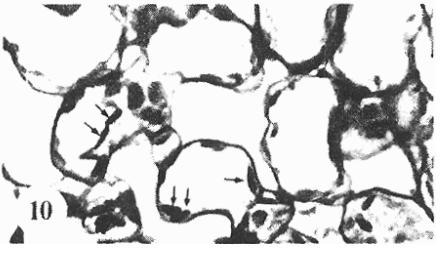
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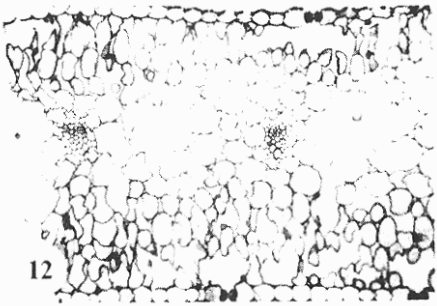

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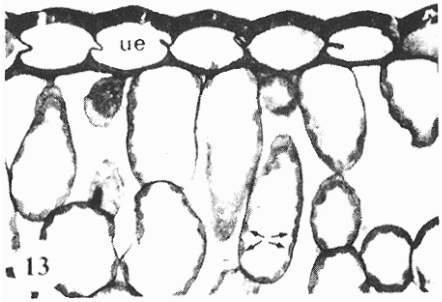

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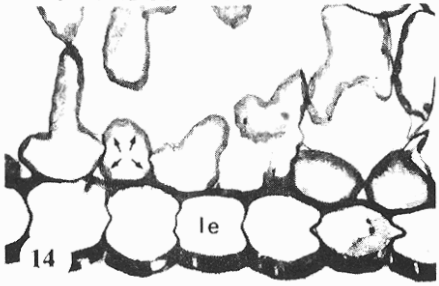

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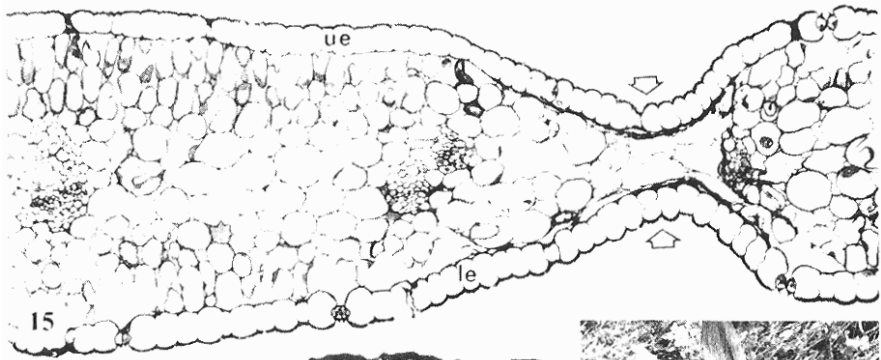

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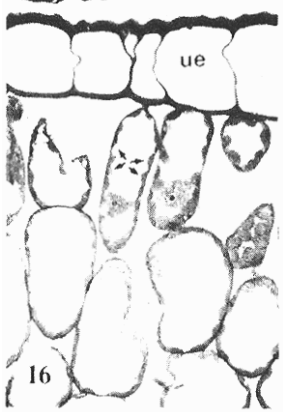

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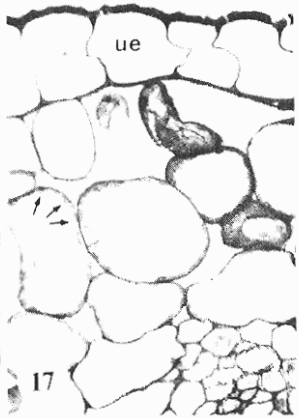

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LEGENDS

Figures 1-10. *Phlomis fruticosa*

Figures 1-5. Plant material from an area free from air pollutants (Varkiza).

Figures 6-10. Plant material from an area where the presence of smog is evident (Korydalos).

Figures 1,6. The two last pairs of leaves. Samples were taken always from the second pair of leaves (asterisk). Notice that perturbated leaves (Figure 6) show several light areas (Both X2/3).

Figures 2,7. Light micrographs of cross sectioned leaves (X70).

Figures 3,8. Cross sections of leaves·note the abundance of chloroplasts in Figure 3 in comparison to those in Figure 8 (Both X300).

Figures 4,9. Palisade parenchyma cells from cross sectioned leaves; chloroplasts are indicated by arrows (X700).

Figures 5,10. Spongy parenchyma cells from cross sectioned leaves; arrows indicate chloroplasts (X700).

Figures 11-18. *Urginea maritima*

Figures 11-14. Plants from an undisturbed area (Varkiza).

Figures 15-18. Plants suffering from smog (Korydalos).

Figures 11,18. The whole plants (Both X1/10). The leaves of the perturbated plant (Figure 18) show abundant pale areas.

Figures 12-14. Cross sections of a leaf (Figure 12, X70). A portion of the upper epidermis with chlorenchyma is magnified in Figure 13 (X300). A portion of the lower epidermis with some chlorenchyma is magnified in Figure 14 (X300). Chloroplasts are indicated by arrows.

Figures 15-17. Cross section of a leaf. Narrow areas (open arrow heads) with fewer mesophyll cells without chloroplasts are present at the pale spots of the leaves (Figure 15, X70). Chloroplasts seem to be not affected in shape and number in distal areas from the narrowing (Figure 16, X300) while they seem to be fewer and smaller in proximal regions (Figure 17, X300).