CUTICULAR FEATURES AS INDICATORS OF ENVIRONMENTAL POLLUTION

G. K. SHARMA, Department of Biology, University of Tennessee at Martin, Martin, Tennessee, USA 38238

ABSTRACT

Several leaf cuticular features such as stomatal frequency, stomatal size, trichome length, type, and frequency, and subsidiary cell complex respond to environmental pollution in different ways and hence can be used as indicators of environmental pollution in an area. Several modifications in cuticular features under polluted environments seem to indicate ecotypic or survival significance for the plant species under investigation.

INTRODUCTION

Numerous studies have revealed the detrimental effects of environmental pollution on plants under natural and controlled conditions. Hill and Thomas (1933) reported that sulfur dioxide decreased the yield of alfalfa. Chamberlain (1934) observed that dirt, smoke, and the gases of a large city were fatal to conifers, especially *Pinus banksiana*. The plants showed chlorosis and necrosis. Solberg and Adams (1956), reported that fluoride and sulfur dioxide destroyed the spongy mesophyll and the lower leaf epidermis of plants. Scheffer and Hedgcock's (1955) study of the forests of the Northwestern United States revealed the characteristic effects of sulfur dioxide injury on leaves. Pyatt (1970) investigated lichens as possible biological indicators of air pollution in a steel-producing town in Wales and found that generally the lichen flora decreased in number of species present with increasing proximity of the source of pollution. Feder (1970) recorded a decrease in floral productivity and branching in geranium subjected to oxidant-type pollutants. It was quite evident from a survey of literature that the possibility of utilizing leaf cuticular and morphological features as indicators of environmental pollution needed investigation, although their significance in taxonomic and ecological studies is well documented (Au, 1969; Sharma and Dunn, 1969; Sharma, 1972). Therefore, the purpose of this report is to indicate the progress achieved in establishing the concept of using leaf cuticular patterns in studying environmental pollution.

MATERIALS AND METHODS

White clover *(Trifolium repens L.)*, red clover *(Trifolium pratense L.)*, and sweetgum *(Liquidambar styraciflua L.)* plant populations were studied in the rural and metropolitan areas of Kentucky and Tennessee, USA. Mature leaf samples were collected in summer to make slides of the upper and lower epidermis using Duco cement (Williams, 1973). These slides were used to study cuticular features such as stomatal frequency, stomatal size, trichome length, type, and frequency, and subsidiary cell complex. Floral productivity and leaf size were also studied in the plant populations of relatively unpolluted and polluted habitats. The type and major sources of pollution in four study areas in Tennessee are indicated in Table 1.

TABLE 1: DISTRIBUTION AND ENVIRONMENT OF RED CLOVER POPULATIONS

Population	Number of samples	Location*	Type of pollution	Source of pollution
A	3	Reelfoot Lake	Sulfur dioxide, ozone	Vehicular traffic
B	3	Memphis	Sulfur dioxide, particulate matter, carbon monoxide, other oxidants	Vehicular traffic, jet airport power plant, manufacturing plant, other industrial units
C	3	Nashville	Particulate matter, sulfur dioxide, carbon monoxide other oxidants	Vehicular traffic, power plant, jet airport, fertilizer plant, textile plant, other industrial units
D	3	Knoxville	Sulfur dioxide, particulate matter, carbon monoxide, other oxidants	Vehicular traffic, power plant, air port, manufacturing plant, other industrial units

* in Tennessee, U.S.A.

RESULTS AND DISCUSSION

The morphological and cuticular findings in the selected populations of red clover and white clover are summarized in Tables 2 and 3 (Sharma and Butler, 1973, 1975). It was found that in the large, metropolitan, industrial cities of Memphis, Nashville, and Knoxville the stomatal frequency values were lower than the measurements made in the rural, relatively unpolluted or less polluted area near Reelfoot Lake in northwest Tennessee. This adaptation could decrease the amount of poisonous gases getting into leaf tissues and thus protect the plant against pollution. The populations in polluted areas had

TABLE 2: SUMMARY AND COMPARISON OF LEAF CUTICULAR PATTERNS AND FLORAL PRODUCTIVITY IN RED CLOVER POPULATIONS

Trait		Population A	Population B	Population C	Population D
Stomatal frequency ($\bar{x}$±б)	upper	25.9±6.0	14.4±3.4	13.9±4.1	17.1±3.4
	lower	59.3±9.5	44.6+2.5	43.3±7.9	47.2±9.7
Stomatal size range (μ)	upper	8-10	8-15	8-15	8-16
	lower	8-16	8-14	8-16	8-15
Trichome density/cm^2	lower	80	220	196	175
Trichome length, μ ($\bar{x}$)		283	366	379	336
Subsidiary cell complex (cells)		3-4	3-4	3-4	3-4
Avg. number of flowers/ inflorescence		87	61	56	67

$\bar{x}$=mean
б=standard deviation

TABLE 3: LEAF CUTICULAR FEATURES AND FLORAL PRODUCTIVITY IN WHITE CLOVER POPULATIONS

Trait		Population A	Population B
Stomatal frequency ($\bar{x}$±б)	upper	153.4±14.1	96.8±10.3
	lower	44.3± 9.6	37.2± 7.8
Stomatal size range (μ)	upper	10-15	7-17
	lower	17-25	15-25
Trichome density/cm^2	lower	* U=25	U=60
		** M=60	M=123
Trichome length, μ ($\bar{x}$)		82	95
Subsidiary cell complex (cells)		3-4	3-4
Avg. number of flowers/ inflorescence		69	47

$\bar{x}$= mean
б= standard deviation
U*= unicellular trichome
M**= multicellular trichome

barbed, longer, and more trichomes on their leaf surfaces. This adaptation would have the effect of lowering the average leaf temperature and hence decreasing the rate of metabolic reactions associated with various harmful gases in and around leaves (Fig. 1A). The long, barbed trichomes also might act as filters and insulators and keep the dust particles away from stomatal openings (Fig. 1B). The trichomes in red clover leaves were unicellular and had a ring of elongated cells around their base (Fig. 1C). White clover had both unicellular and multicellular trichomes on their lower leaf surfaces (Table 3).

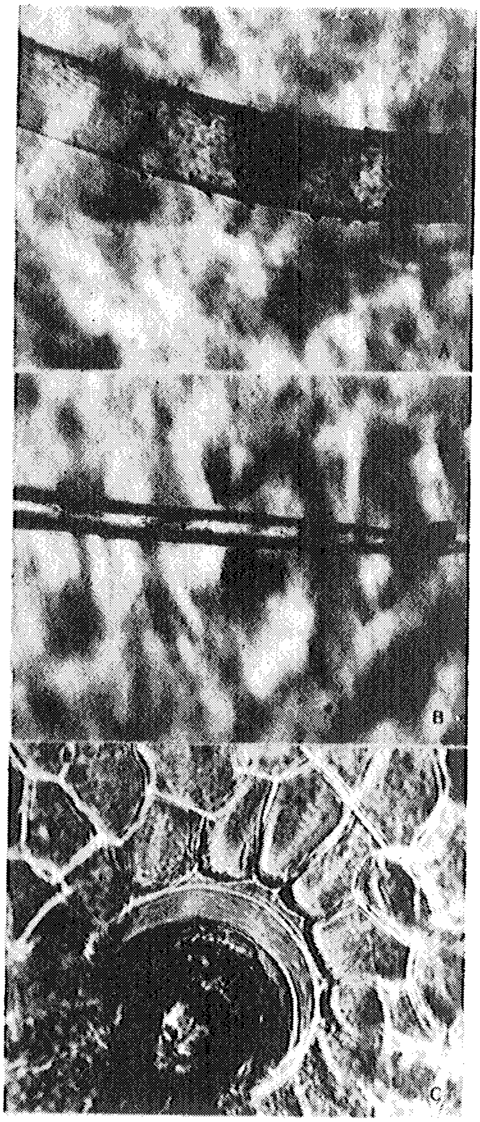

Figure 1. Trichomes in *Trifolium pratense L.*

A. Showing 'barbed' surface, 200X.

B. A simple, pointed trichome with a trapped dust particle, 100X.

C. A ring of elongated cells around trichome base, 200X.

Production of flowers was low in polluted-area populations. Subsidiary cell complex and stomatal size range remained unaffected by pollution within a plant species. Similar results were obtained in sweetgum and sugar maple populations (Sharma and Tyree, 1973; Sharma, 1975).

CONCLUSIONS

It is evident that environmental pollution retarded production of flowers in the plant species investigated. Stomatal frequency decreased in polluted area populations while trichome density and trichome length increased. Subsidiary cell complex and the stomatal size range were not affected by environmental pollution. It is, therefore, concluded that these features can be used as indicators of environmental pollution in an area. It is further suggested that such patterns in the plants of polluted areas may be of significance in determining the degree and perhaps the type of pollution.

REFERENCES

Au, S. F. 1969. Internal leaf surface and stomatal abundance in arctic and alpine populations of *Oxyria digyna*. ECOLOGY 50: 131-134.

Chamberlain, C. J. 1934. GYMNOSPERMS: STRUCTURE AND EVOLUTION. Dover, New York.

Feder, W. A. 1970. Plant response to chronic exposure to low levels of oxidant type air pollution. ENVIRON. POLLUT. 1:73-79.

Hill, G. R., Jr. and M. D. Thomas. 1933. Influence of leaf destruction by sulfur dioxide and clipping on yield of alfalfa. PLANT PHYSIOL. 8:334-345.

Pyatt, B. F. 1970. Lichens as indicators of air pollution in a steel producing town in South Wales. ENVIRON. POLLUT. 1:45-55.

Scheffer, T. C. and G. C. Hedgcock. 1955. Injury to northwestern forest trees by sulfur dioxide from smelters. U.S. DEP. AGR. TECH. BULL. 1117. 49 pp.

Sharma, G. K. 1972. Environmental modifications of leaf epidermis and morphological features in *Verbena canadensis*. SWEST. NAT. 17:221-228.

______ 1975. Leaf surface effects of environmental pollution on sugar maple (*Acer saccharum*) in Montreal. CAN. J. BOT. (in press).

______, and J. Butler. 1973. Leaf cuticular variations in *Trifolium repens L.* as indicators of environmental pollution. ENVIRON. POLLUT. 5:287-293.

_____, and ______. 1975. Environmental pollution: leaf cuticular patterns in *Trifolium pratense L.* ANN. BOT. (in press).

_____, and D. B. Dunn. 1969. Environmental modifications of leaf surface traits in *Datura stramonium*. CAN. J. BOT. 47:1211-1216.

_____, and J. Tyree. 1973. Geographic leaf cuticular and gross morphological variations in *Liquidambar styraciflua L.* and their possible relationship to environmental pollution. BOT. GAZ. 134: 179-184.

Solberg, R. A. and D. F. Adams. 1956. Histological responses of some plant leaves to hydrogen fluoride and sulfur dioxide. AM. J. BOT. 43:755-760.

Williams, J. A. 1973. A considerably improved method for preparing plastic epidermal imprints. BOT. GAZ. 134:87-91.