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THE EFFECT OF AIR POLLUTION ON *SOPHORA JAPONICA* (LEGUMINOSAE) AND *EULECANIUM GIGANTEUM* (SHINJI) (HEMIPTERA: COCCOIDEA: COCCIDAE) IN URBAN AREAS IN CHINA.

ABSTRACT

THE EFFECT OF AIR POLLUTION ON *SOPHORA JAPONICA* (LEGUMINOSAE) AND *EULECANIUM GIGANTEUM* (SHINJI) (HEMIPTERA: COCCOIDEA: COCCIDAE) IN URBAN AREAS IN CHINA.

A study was made of the effect of two air pollutants (sulphur dioxide and lead) on the pest status of the soft scale *Eulecanium giganteum* (Shinji) and on the accumulation of sulphur and lead in the scale's host tree, *Sophora japonica,* in three cities in China, namely Taiyuan, Yuci and Taigu. *E. giganteum* is a major pest of several tree species in many cities in China where air pollution can be high. This study showed a positive correlation between the level of the pollutants in the trees and the populations of the scale. The leaves absorbed and accumulated a greater amount of sulphur dioxide (SO_2 - as sulphur) and lead (Pb) than the twigs, but the trends were the same in each, namely with high levels in these tissues in the Spring and early Autumn. It is concluded that *E. giganteum* can withstand high levels of pollutants, both within the host plant and in the environment, whereas its natural enemies may not.

Key words: urban areas, biology, percentage parasitism, sap quality, pollution levels, *Beijing utila*, *Microterys clauseni*, *Blastothrix sericea*, *Eucomys sasakii*, *Anisetus*, Coccinellidae, Helicodinidae, Encyrtidae, *Coccinella septempunctata*, *Harmonia axyridis*, *Chilocorus rubidus*.

INTRODUCTION

Eulecanium giganteum (Shinji) (Coccoidea: Coccidae) is one of the most important scale insects in urban areas in China. A study of the effects of pollution on the populations of this insect have been undertaken since 1993 and have shown that the population density of *E. giganteum* is positively correlated with traffic pollution (Xie *et al*., 1995), with the pollutants being found in the bodies of both the host plants and the scales (Xie *et al.*, 1998). This paper considers the correlation between the levels of two pollutants, sulphur dioxide and lead, in the host plant and the population densities of *E. giganteum*. This is discussed in relation to the biology of the scale.

MATERIALS AND METHODS

Three sites of relatively high pollution and two sites of low pollution were studied. The former were (a) the city of Taiyuan, capital of Shaixi Province: an area of heavy industry, where the pollution is mainly from vehicular exhaust gases and which is considered to be the most polluted area in China. Some four districts of Taiyuan were studied: Railway Station Street, City Centre Square, Bus Station Street and Xin Jian Road. (b) The city of Yuci, which has light industry and is about 30km south-west of Taiyuan. Two districts were studied: Liang Dian Street and Shun Cheng Street. (c) The county town of Taigu, some 60km south of Taiyuan, where the pollution is from heavy industry such as iron and steel making and from chemical factories which use a lot of coal. The two less polluted sites were Jinsi Park, in the southern suburbs of Taiyuan, and the Botanical Gardens of Shanxi Agricultural University, Taigu.

Samples of *Sophora japonica*, a common tree in suburban areas and a good host for *E. giganteum*, were taken monthly as follows: first, 10-15 sample trees were selected in the particular street and then five twigs were taken from each tree and the number of scales insects on 60cm of the twig tip counted. Most of the sampled trees were 10-20 years old. The plant samples were taken to the laboratory where they were washed to remove the dust.

Sulphur dioxide (SO_2 - as sulphur) analysis: the twigs and leaves were separated, dried and ground for chemical analysis. Triplicate samples were digested in a nitric acid/perchloric acid mixture and the diluted digests analysed for sulphur as barium sulphate by turbidimetry using a spectrophotometer.

Lead (Pb) analysis: the samples were dried and 5g were placed in a crucible and reduced to ash in a muffle furnace. The ashes were then dissolved in HNO_3 and the amount of lead determined by atomic absorption spectroscopy.

RESULTS

LEAD: the results of the analysis for each district are presented in Table 1 and are compared with the soft scale populations. The level of lead in the twigs and leaves was very similar for each district. The greatest lead concentration was in Taiyuan and the lowest concentration in the Botanical Gardens. The scale population was also greatest in Taiyuan and least in the Botanical Gardens. Indeed, the correlations between the scale population and the level of Pb was highly significant ($r = 0.96$ for the twigs and 0.99 for the leaves).

Table 1. The population density of *E. giganteum* per 60cm of twig and the amount Pb (ppm) in the twigs and leaves of *Sophora japonica* in 10 districts in northern China (mean of 9 observations).

Area	District	No. scales	Pb (twigs)	Pb (leaves)
Taiyuan	Railway Stn St.	123.5	9.00	8.49
	Bus Stn St.	120.0	8.25	8.25
	City Centre Sq.	115.2	7.49	7.74
	Xin Jian Rd	106.3	6.25	7.00
Mean		116.2	7.75	7.87
Yuci	Liang Dian St.	76.5	6.90	5.25
	Shun Cheng St.	56.2	5.00	4.25
Mean		66.4	5.95	4.75
Taigu	Taigu town 1	52.8	4.00	4.50
	Taigu town 2	27.0	3.00	2.25
Mean		39.9	3.50	3.13
Taiyuan	Jinsi Park	4.6	1.99	1.33
Taigu	Botanical Gdns	1.3	-	-

Where - = level of Pb too low to record. Correlation equations: twigs: Y_1 = -23.7630 +17.2698X (r = 0.96); leaves: Y_1 = -14.6250+16.5861X (r = 0.99).

SULPHUR DIOXIDE: the results of the analysis (as sulphur (g/kg)) for each district are presented in Table 2 and are compared with the soft scale population. The samples from all three polluted cities had similar high levels of SO_2, some two times greater than in the less polluted district of the Botanical Gardens, Taigu. Thus, unlike the levels of Pb (Table 1), the levels were equally high in Yuci and Taigu, even though the scale populations were clearly not as large. Nonetheless, the correlations between the scale population and the level of SO_2 were still significant (r = 0.71 for twigs and 0.81 for leaves).

Monthly variations: the variation in Pb and sulphur levels in the twigs and leaves of *S. japonica* at approximately monthly intervals in the four sites of Taiyuan City is shown in Fig. 1. There appear to be two peaks with high levels of the two pollutants, one in the Spring (March to May) and the other in the late Summer/early Autumn (August to October), with a very significant drop in the levels of the two pollutants during the Summer (June/July).

Table 2. The population density of *E. giganteum* per 60cm of twig and the amount of sulphur (g/kg) in the twigs and leaves of *Sophora japonica* at 7 sites in northern China (mean of 9 observations).

Area	Site	No. scales	S (twigs)	S (leaves)
Taiyuan	Railway Stn. St	123.5	1.958	7.094
	Bus Stn. St.	120.0	1.632	6.457
	City Centre Sq.	115.2	1.568	6.212
	Xin Jian Rd.	106.3	1.418	5.755
Mean		116.3	1.644	6.380
Yuci		76.5	1.679	6.316
Taigu		39.9	1.624	6.079
Botanical Gds		1.3	0.951	3.978

Correlation equations: twigs: Y_1 = -84.4612+108.3969X (r = 0.71); leaves: Y_1 = -149.7997 +38.9417X (r = 0.81).

DISCUSSION

Previous work looking at the effect of vehicle pollutants on aphids (*Aphis pomi*) (Flückiger *et al.*, 1978) found an upsurge in the aphid population on hawthorn (*Crataegus monogyna*) with increasing levels of pollutants, while Beyer & Moore (1980) found that the eastern tent caterpillar (*Malacosoma americanum* (F.) and its host plant (black cherry, *Prunus serotina* (Rosaceae)) absorbed lead from the atmosphere near a motorway near Baltimore, USA. Previous work with *E. giganteum* has shown that its population levels are positively correlated to the level of pollution from traffic (Xie *et al.*, 1995) and that the pollutants can be detected in both the host plants and in the scale (Xie *et al.*, 1998). Environmental records for the level of air pollution in Taiyuan show that the levels fall quite dramatically during the summer, but remain fairly high for the rest of the year, as suggested in Fig. 1. Whilst the correlations between both pollutants and the scale populations were highly significant, the fact that the levels of SO_2 was high in all polluted study areas (Table 2) but the scale populations decreased in a manner similar to the Pb levels (Table 1), suggests that it is the latter pollutant which may be most important.

E. giganteum has a single generation a year. The scale overwinters as a 2nd-instar nymph on the twigs and so, when the host trees are starting to grow fast in the spring (March/April), the scales also grow fast, finally

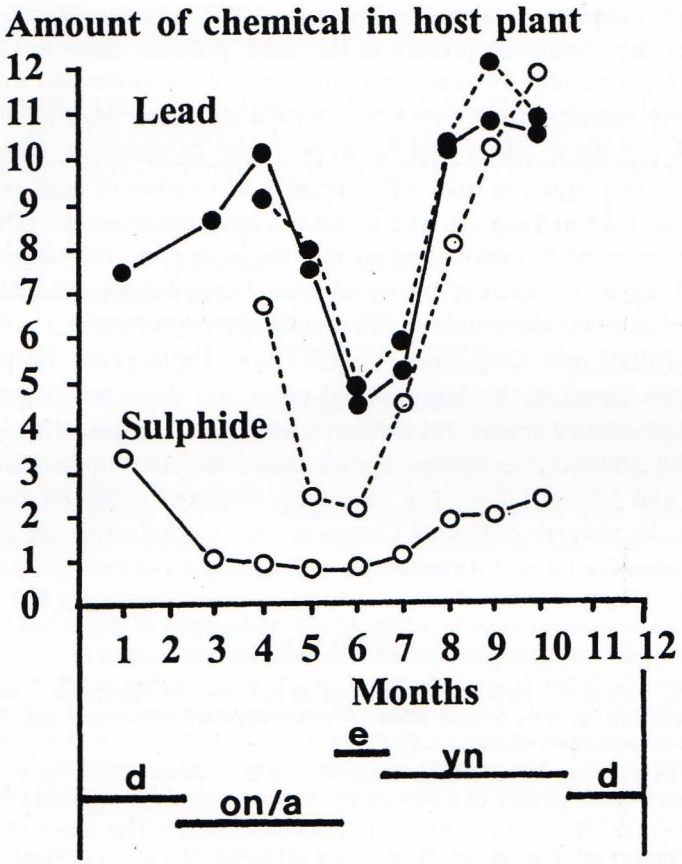

Fig. 1. Fluctuations in sulphur (g/kg) and lead (ppm) in the twigs and leaves of *Sophora japonica* in 1996 in Taiyuan City. Where • = lead; o = sulphide; —— = twigs and -- = leaves; and where **e** = eggs of *E. giganteum*, **yn** = 1st- and 2nd-instar nymphal feeding stage; **d** = dormant period, and **on/a** = 3rd-instar nymphs and adult feeding stage.

becoming adult in late April or early May when the host trees are in their period of maximum growth. The females lay eggs in May and these hatch towards the end of June, with the young nymphs dispersing to the leaves. They remain on the leaves until October but then disperse back to the woody parts of their host to overwinter. Thus, it is mainly the non-feeding egg stage of *E. giganteum* which is present during the early summer when the pollution levels are low; the nymphs and adult females are actively feeding during the two periods of high pollution (March to May and August to October).

Although excessive pollution is very harmful, *E. giganteum* appears to do well under the conditions present in the more polluted cities in China. This could be for a number of reasons: i. an effect of the pollutants might be to improve the nutritional quality of *S. japonica* and other host plants, so that the scales can grow larger and be more fertile (preliminary trials in 1996 suggest that this could be true, with the greatest number of eggs per scale in Taiyuan and least in Taigu); ii. the pollutants have a detrimental effect on the natural enemies of *E. giganteum*, so that the scales are no longer properly controlled (again, preliminary counts of natural enemies suggest that there are more predators (Coccinellidae: *Coccinella septempunctata* L., *Harmonia axyridis* (Pallas) and *Chilocorus rubidus* Hope; Lepidoptera, Helicodinidae: *Beijing utila* Yang) in the less-polluted areas and these are believed to be important biocontrol agents. No ladybirds were noted in the polluted areas of Taiyuan. In addition, percentage parasitisation was 14% in Taiyuan, 26% in Yuci City and 37% in Taigu). The parasitoids found in *E. giganteum* were the encyrtids *Microterys clauseni* Compere, *Blastothrix sericea* (Dalman), *Eucomys sasakii* Ishii and *Anisetus* sp.

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