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Effect of SO_2-polluted rape plant on growth and reproduction of the turnip aphid, Lipaphis erysimi (Kaltenbach)*

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Abstract——A series of experiments using open-top fumigation chambers was carried out to investigate the effect of SO_2-polluted rape on performance of the turnip aphid, *Lipaphis erysimi* (Kaltenbach). Proper SO_2 concentrations significantly enhances growth and reproduction of the aphid. Nymph MRGR and adult fecundity reached their maxima at 116 nl/L and 80 nl/L of the pollutant, respectively. Potential of the population growth got fully displayed at the latter dose because the highest survival rate of the nymphs also took place at this concentration. It is suggested according to changes in the plant chemistry that this indirect effect of SO_2 pollution on the turnip aphid might involve variation in content of individual key free amino acid rather than total amount of all the amino acids in the leaves induced by the air pollutant.

Keywords: SO_2; rape; turnip aphid (*Lipaphis erysimi*); MRGR; fecundity.

1 Introduction

It is well known that host-plant quality is one of important factors, on which performance of phytophagous insects depends. In recent years, a growing number of studies has shown that atmospheric pollutants can affect plant quality sufficiently to modify the relationship between the plants and insects infesting them. Sulphur dioxide (SO_2) is the predominant air pollutant over wide geographical areas, and therefore much attention has been paid to its effect on plant-insect interactions (Hughes, 1982; Warrington, 1987a; 1987b; Wu, 1990; 1992; Houlden, 1990; Gong, 1993).

Aphids have frequently been used in such studies due to their rapid growth and sensitive response to change in food plant quality. A number of researches have showed that growth rate of certain aphid species feeding on SO_2-exposed food plants markedly increased (Warrington, 1987a; Dohmen, 1988; Houlden, 1990; Wu, 1992). Usually, such studies only used one concentration of SO_2 with charcoal-filtered air as control. In nature, however, its pollution level varies from time to time and from place to place. Furthermore, effect of SO_2 pollution on aphid fecundity has rarely been reported (Warrington, 1987b; Wu, 1992). The

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experiments described here examine changes in both growth and fecundity of the turnip aphid, *Lipaphis erysimi*, feeding on the rape leaves prefumigated with a wider range of SO_2 concentrations.

2 Material and methods

2.1 Food plant

Rape (*Brassica chinensis* L. c. v. Siyueman) was sown in pots (17 cm dia. × 14 cm high) containing a mixture of loamy soil, peat and horse dung (1 : 1 : 2) in late March. Three weeks later, the seedlings were thinned to 3 individuals per pot. They were put at random into each of 5 open-top environmental chambers (Shu, 1986) in mid-May and received SO_2 fumigation until the end of the experiment. The control plants were exposed to charcoal-filtered air. Fumigation was run from 8:30 to 16:30 every day except Sunday. After two-week exposure, the rape leaves with similar age were taken to raise the aphids. The plants were well-watered throughout the experiment. The SO_2 concentrations in these chambers were monitored daily with a Dasibi 4801 Sulphur Dioxide Analyzer and averaged 9.8 (control), 39.1, 80.1, 116.4 and 155.5 nl/L, respectively.

2.2 Insect culture

A colony of the turnip aphid, *Lipaphis erysimi* (Kaltenbach) originated from several apterous adults collected in greenhouse-grown rape and was kept on their leaves in laboratory. Fresh weight of the nymph aphids born within 12h was taken in groups of 50 individuals to get their initial mean, and then transferred them with a fine paint brush onto the rape leaves of different treatments, 4 nymphs per leaf. They were reared in 25 ml beaker. The containers were covered by a piece of white muslin and plastic sheet, on which a few small holes were punched for air exchange.

Rearing experiments were performed in one climatic chamber at 24±1℃ and 12h photophase. The leaves were renewed daily. On the 6th day from rearing each of these nymphs was weighed again and their mean relative growth rate (MRGR) during this period of time was calculated (Van Emden, 1969).

A set of parallel experiments was arranged to examine performances of the adult aphids. All the adults tested were apterous. They were separately kept in the container and the offspring produced by them was counted and removed daily. Intrinsic rate of increase (r_m) of these populations was calculated using the formula of Wyatt and White (Wyatt, 1977):

$$r_m = 0.74\ (\log_e M_d)/d$$

where d is the number of days from birth to first reproduction (the prereproductive period) and M_d is the number of progeny produced during a period of 'd' days from the first birth.

2.3 Analysis of plant chemistry

The rape leaves of similar age were sampled when rearing experiment started. Changes in their main components, namely water, S, reducing sugar and free amino acid were determined following the procedures described previously (Wu, 1990).

2.4 Data process

A multiple range test (Duncan, 1955) was applied for analysis of differences among treatments with significance at the 5% level and the data are expressed as mean±*SE*.

3 Results

3.1 Nymph performance

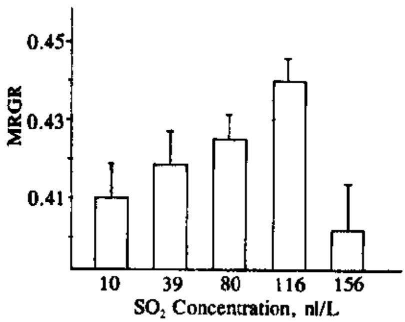

Fig. 1 MRGR of nymph aphids feeding on rape leaves exposed to SO_2 of different doses

The newly-born nymphs averaged 35 μg and grew to be between 0.17 mg and 0.40 mg after 5-day-feeding on the leaves of different treatments. There was a clear increase in their MRGR with elevating SO_2 concentration up to a peak of 9.1% above control, which occurred at 116 nl/L of the pollutant. Then, the parameter sharply declined at the higher SO_2 dose (Fig. 1). The nymphs survived most in the case of 80 nl/L SO_2 while their durations were significantly shorter in a range of 39—116 nl/L SO_2 than other treatments (Table 1).

Table 1 Performance of turnip aphid on rape leaves exposed to SO_2*

SO_2 dose, nl/L	10 (control)	39	80	116	156
Nymph stage (n=80)					
Duration, d	6.64±0.27a	6.02±0.14b	6.04±0.15b	6.05±0.15b	6.85±0.11a
Survival rate, %	57.5	70.0	87.5	78.8	73.4
Adult stage (n=15)					
Life span, d	3.43±0.36a	3.50±0.25a	6.33±0.83b	4.13±0.25a	4.23±0.44a
No. progeny laid	6.4±0.9a	8.3±0.5a	18.6±3.6b	6.6±1.7a	6.8±3.0a
Population parameter					
r_m, mg/(mg.d)	0.1929	0.2306	0.2969	0.1933	0.1879
Generation time, d	9.65	9.09	8.81	8.93	9.77
Index of population trend	3.70	4.30	16.25	5.22	4.70

*: means followed by different letters differ significantly at $p<0.05$

3.2 Adult performance

Average of offspring produced by adult aphids feeding on the leaves prefumigated with SO_2 of 80 nl/L topped 18.6, much greater than other groups (Table 1).

3.3 Population parameter

Index of population trend of the aphid at 80 nl/L SO_2 was over 4 times that of control while the generation time of all these populations varied within one day (Table 1).

3.4 Change of plant chemistry

Both water and reducing sugar contents varied a little among the treatments, but never greater or less than 4% of those in control leaves while leaf S content kept increasing in response to elevating SO_2 and its content at the highest dose of the pollutant doubled the control. Total amount of free amino acids in the leaves varied considerably with the maximum and the minimum occurred at 116 nl/L and 80 nl/L SO_2, respectively (data not shown). Consistent changes, both positive or negative relative to control, were detected for the contents of all the individual amino acids, among which variation of methionine concentration was interesting. Its absolute content increased a lot in all the SO_2-exposed leaves, and its relative content (the percentage accounting for the sum of all the amino acids examined) varied in the way somewhat similar to that of r_m of these populations (Fig. 2).

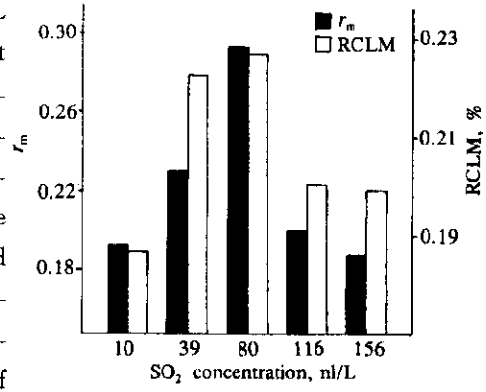

Fig. 2 Comparison between r_m of *L. erysimi* populations and relative content of leaf methionine (RCLM) at different doses of SO_2

4 Discussion

The results showed that SO_2 pollution at proper level markedly enhanced growth and reproduction of the turnip aphid, which is in accordance with that reported by other authors (Warrington, 1987a; 1987b; Dohmen, 1988; Houlden, 1990; Wu, 1992). A remarkable feature of this aphid species in response to SO_2 was the best performances of its immature and mature stages appearing at different doses of the pollutant. MRGR of the nymphs reached the peak at 116 nl/L SO_2 while the maximum fecundity of the adults occurred at 80 nl/L SO_2. Such a pattern differs from that of *Myzus persicae*, whose greatest MRGR and fecundity took place at the same concentration of the pollutant (Li, 1992). Potential of population growth of the turnip aphid got fully displayed at 80 nl/L SO_2(Fig. 2) because the highest survival rate of the nymph also occurred at this concentration (Table 1). The observed effect of SO_2 pollution on the aphids is certainly of great economic importance since they damage crops not only directly by exploiting the plant nutrients but also as vectors of plant viral diseases.

It is established that growth of aphids responds well to SO_2 pollution. Among the aphid species examined, the increase in MRGR averaged 11% for *Acyrthosiphon pisum* at SO_2 concentrations between 90 nl/L and 110 nl/L (Warrington, 1987a), 6% for *Aphis fabae* at SO_2 doses in a range of 90—230 nl/L (Dohmen, 1988), 22% with a range from 7% to 40% for 8 aphid species in UK at some 100 nl/L SO_2(Houlden, 1990) and 31. 5% for *Myzus persicae* at 80 nl/L SO_2(Wu, 1992) as compared with respective control. Thus, a 9. 1% increase in MRGR of *L. erysimi* at 116 nl/L SO_2 falls at lower end of the parameter's increment.

The SO_2 concentrations used in present experiment were chosen to outline air quality of our country. For example, average SO_2 concentrations in atmospheres of 23 key cities were monitored to vary from 30 nl/L to 247 nl/L in the first quarter and from 19 nl/L to 97 nl/L in the 2nd one of 1987 (Chen, 1991). Air quality in rural areas has also been becoming poorer due to booming rural enterprises. It is estimated that SO_2-polluted farmland had been beyond 3 million hectars, among which about one third was directly caused by emission from rural industry (Zhang, 1986). All of these imply that severer infestation of certain aphid species on their host plants had occurred in the polluted areas than elsewhere.

The mechanism by which insects feeding on SO_2-polluted plants performed better had not been elucidated, but the investigations done so far indicated that this impact was entirely mediated via the host plants and change in content of amino acids of the polluted-plants might play a key role in this respect since it is able to affect performance of insect, particularly aphids (Dohmen, 1984; Houlden, 1990; Wu, 1992). Qian *et al.* (Qian, 1992) reported that SO_2 exposure of rape plant for only a few hours led to marked increase in all the 10 amino acids essential to insects, but the SO_2 concentrations used by them were too high (the lowest being 500 nl/L) to explain the present results. Our determination showed more or less similarity of change in r_m of the aphid populations to that of relative content of methionine , a S-containing amino acid which is indispensable to insect life (Fig. 2). This finding suggests that such indirect effect of SO_2 pollution on the turnip aphid might involve variation of individual key amino acid rather than the total amount of all the amino acids in the leaves induced by the pollutant. It is obvious that more investigations on a wider range of SO_2-plant-insect systems and the precise mechanism underlying such interactions are in great need.

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