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Effect of airborne SO_2 on performance of the turnip moth, *Agrotis segetum* Schiff.

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Abstract — Effect of SO_2-enriched air on the turnip moth, *Agrotis segetum* Schiff. was investigated by rearing the larvae on rape leaves that had been exposed to 40 or 80 ppb of the air pollutant in field fumigation chambers. An examination on the 11th day showed that the larvae in both treatments survived more, developed markedly faster, their fresh weight and mean relative growth rate were significantly greater than those of control insect. Improvement of their growth and development resulted in decrease of total larval duration by 0.5–1.0 day. Pupal and adult performances were little affected by SO_2 level to which larval food plant was exposed. Possible reason responsible for enhanced growth and development of the insect species was discussed.

Keywords: SO_2 Pollution; rape plant (*Brassica chinensis*); turnip moth (*Agrotis segetum*); growth and developmental parameters.

In the course of long-term coevolution, a fine balance has developed between plants and insects living on them, in which insects exploit plants while the plants are often marginal as a source of nutrition for the insects. Therefore, both plants and insects are able to exist but neither could realize its full potential (House, 1961; Southwood, 1973; Hughes, 1981). Any changes in this state of equilibrium can produce marked ecological and, in the case of cultivated plants, economic consequences. Such changes can be caused by many factors that affect physiological state of the plants, including stresses such as drought, cultivation measures, diseases, or chemical pollutants.

Sulphur dioxide (SO_2) is one of major air pollutants, mainly emitted from coal-burning. A number of surveys and experiments have showed that increasing SO_2 concentration in air depressed plant photosynthesis, leading to decreased yield of many crops (Linzon, 1978; Cao, 1985). Its adverse effect on human health and development of other animals was also noticed (Petters, 1982). However, investigations in the last decade revealed that some species of insect pests reared on the plants prefumigated or being fumigated with low level of SO_2 performed better and/or caused heavier damage to the crops tested (Hughes, 1982; Dohmen, 1985; Warrington, 1987; Houlden, 1990; Wu, 1990). These results may imply that insect pests represent

a significantly increased danger to our crops in the areas affected by the air pollutant. This is a new challenge for entomologists and researchers in the field of plant protection against diseases and insect pests. At present, however, it is uncertain whether such stimulative effect of SO_2 pollution on insect is a general phenomenon or not. Therefore, study on more species of insects is in great need.

The turnip moth, *Agrotis segetum* Schiff. is a species of insect in *Noctuidae, Lepidoptera,* with larvae infesting seedlings of many crops and vegetables. This paper deals with performance of the insect reared on rape leaves prefumigated with lower doses of SO_2.

MATERIALS AND METHODS

Food plant

Rape (*Brassica chinensis* L cv. Qingbaibang) as food plant for the insect was sown in pots (17.0 cm in dia. × 14 cm high) in early April. Two weeks later, the seedlings were thinned to 3 individuals per pot. Beginning from the 5th week, the rape plants were put into field open-top environmental chambers through which SO_2-containing air went (Shu, 1986). Charcoal-filtered air was driven into the control chamber. Fumigation was run during daylight, 8 h per day, 6 days per week. After exposed to SO_2 for 18 days the rape leaves were taken to raise larvae of the turnip moth. 3 sets of fumigation chambers were employed and SO_2 levels designed were 0 (control), 40 and 80 ppb, respectively. Means of its concentration monitored daily using Dasibi 4801 Sulphur Dioxide Analyzer were 9.8, 39.1 and 80.1 ppb, respectively.

Insect rearing

A colony of the turnip moth, *Agrotis segetum* Schiff. was initiated from the moths collected at Xuzhou Suburbs, Jiangsu Province and has been raised on the lambsquarters-wheat germ artificial diet (Wu, 1988) for 2 years in the laboratory. After hatching from eggs, the neonate larvae in group were reared on rape leaves exposed to SO_2-enriched air in glass jar(7.5 cm in dia. × 4.5 cm high) until entering the 4th instar. Then single caterpillars were kept in each of 25 ml beakers through pupation. Couples of adult moths were separately held in glass chimney (10 cm in dia. × 10 cm high) above a jar with some water. A 10% bee honey solution was offered as their supplemental nutrient. Larval and adult foods were renewed daily. Rearing experiment was conducted at 25 ± 1℃ with a 12L:12D photoperiod in a climatic chamber.

Recording and analysis of data

Larval development and survival as well as adult fecundity and longevity were monitored daily. Fresh weights of larvae on the 11th day and of two-day-old pupae

were taken. The former was used to calculate their mean relative growth rate (MRGR) according to Van Emden (1969):

$$MRGR = \frac{\ln(\text{final weight}) - \ln(\text{initial weight})}{\text{Growth time in day}}$$

The *t*-test was used to determine significance of differences between data from the insects received different treatments when necessary.

RESULTS AND ANALYSES

Effect on survival of the larva and pupa

During fumigation period, no apparent injure spot on the leaves was observed. After reared on the leaves exposed to low doses of SO_2 for 10 days, survival rate of the larvae was 9% –13% higher than that on control food plant (Table 1). Similarly, pupation and eclosion percentages of these caterpillars were greater in comparison with those on the leaves received unpolluted air.

Table 1 Survival of the turnip moth on food plant exposed to different doses of SO_2

SO_2 dose, ppb	Control	40	80
No. larvae tested	70	56	76
No. larvae died within 10 days	20	11	12
Survival, %	71.4	80.4	84.2
No. pupae formed	43	42	54
Pupation, %	61.4	75.0	71.1
No. moth emerged	42	38	52
Eclosion, %	60.0	67.9	68.4
S content in rape leaves, mg/g dry wt.	22.19	32.82	41.25

Effect on growth and development of immature stage

An examination in growth and development of the larvae on the 11th day showed that the caterpillars in both treatments performed better than those in control. Firstly, their developmental progress within the first 10 days was faster (Fig. 1). Although majorities of the caterpillars in all the groups were in the 4th instar, nearly a quarter of larvae on the leaves exposed to clean air remained at the 3rd instar while the larvae in the same instar in SO_2-treated groups only accounted for less than 5% of the total. In addition, out of 64 individuals alive on the leaves received 80 ppb of SO_2, 2 larvae, or 3.1%, had entered the 5th instar.

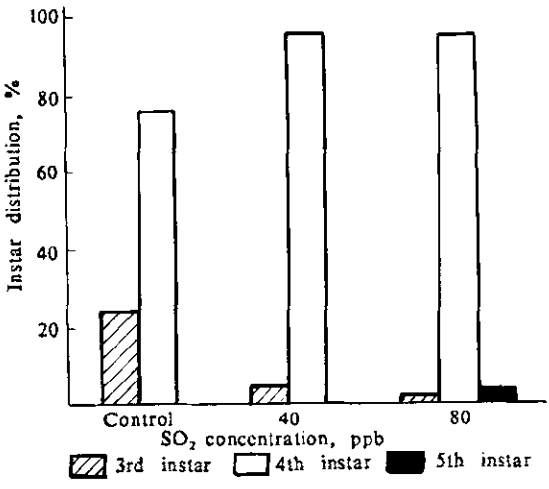

Fig.1 Instar distribution of 11-day-old larvae reared on rape leaves exposed to different SO_2 doses

Secondly, mean relative growth rates (MRGR) of the larvae in both treatments were significantly greater as compared with that in control group (Fig.2). MRGR of the larvae on the food plant fumigated with 80 ppb of SO_2 was the greatest, but it did not differ significantly from that on the leaves treated by 40 ppb of SO_2.

Thirdly, mean fresh weight of the 11-day-old larvae on SO_2-fumigated leaves was markedly greater relative to that from control group (Table 2). Distribution of larval weight was illustrated in Fig. 3. Percentage of the larvae weighed less than 100 mg decreased with increase in SO_2 concentration received by their food plant. In control group, only

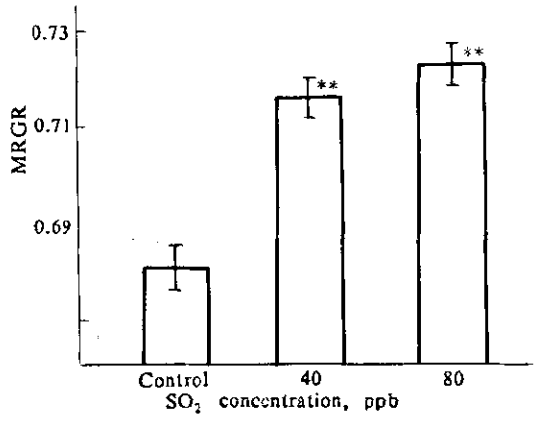

Fig.2 Mean relative growth rate (MRGR) of the larvae within the first 10 days when fed on rape leaves fumigated with different SO_2 doses
** indicate significant differences from control ($p<0.01$)

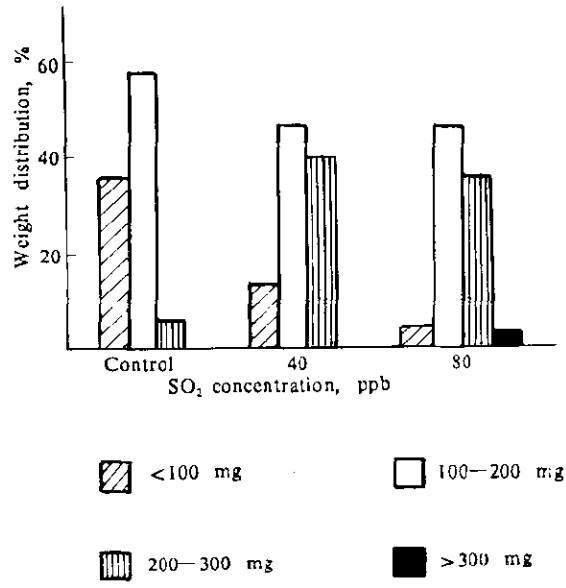

Fig. 3 Fresh weight distribution of 11-day-old larvae reared on rape leaves treated by different levels of SO_2

3 larvae, or 6% of the total, weighed over 200 mg while 36% −40% of individuals in both treatments ranged from 200 mg to 300 mg, and a few larvae on the rape leaves exposed to 80 ppb SO_2 weighed beyond 300 mg. Enhanced growth and development of the larvae in the two treatments resulted in decrease of the total larval duration by 0.5 −1.0 day. However, pupal size and duration were independent of SO_2 dose received by the rape leaves on which larvae were reared (Table 2).

Table 2 Performances of immature stage of the turnip moth on the leaves exposed to different doses of SO_2[1]

SO_2 dose, ppb	Control	40	80
Wt. larvae on 11th day, mg	122.7±6.4a	177.6±7.2b	186.0±7.5b
Larval duration, day	24.09±0.32a	23.07±0.32b	23.48±0.36ab
Pupal weight, mg			
Female	341.1±9.7	335.1±10.9	346.5±8.0
Male	316.6±5.1	315.3±8.0	309.0±9.3
Pupal duration, day			
Female	12.96±0.17	12.89±0.24	12.46±0.17
Male	13.05±0.17	13.22±0.18	13.39±0.19

1. Values in the table indicate mean ±standard error ($M \pm SE$). Means followed by different letters differ significantly at $p < 0.05$

Effect on adult performance

To observe their performances, 11 −12 pairs of adult moths were monitored throughout their life spans. Adults of the turnip moth showed great fecundity under experimental condition. The maximum egg production by individual females reached 2592, which was recorded for the adult from larvae on the food plant fumigated with

Table 3 Adult performances of the turnip moths from larvae on rape leaves exposed to different doses of SO_2

SO_2 dose, ppb	Control	40	80
Mean fecundity			
No. egg laid	1215.3±108.4	1081.3±83.5	1267.1±159.5
No. egg remained in died moths	12.3±2.8	29.4±5.8	18.4±5.8
Total	1227.6±108.3	1110.7±77.8	1285.5±157.3
Mean life-span, day			
Female	13.2±0.8	14.2±1.8	18.5±2.3
Male	14.9±1.6	14.3±1.0	16.9±1.2

80 ppb SO_2. Mean egg production and longevity of female moth in this group increased by 4.3% and 5.3 days, respectively, compared with those of control insect (Table 3). However, these differences were not significant statistically due to great variations among individuals examined.

DISCUSSION

In the ecological point of view, climate change involves alteration of its physical parameters such as temperature, rainfall, light intensity and variation in chemical composition of atmosphere, for example, marked increase of certain trace gases in air, since both of them will exert substantial influence on performance of living things. In some cases, changes in the two categories are closely interrelated. A good example is greenhouse effect which contributes a lot to the global climate warming and is induced by increase of trace gases such as carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFC_s), nitrous oxide (N_2O) and tropospheric ozone (O_3). Besides their greenhouse effects, most of these gases have direct influence on plant photosynthesis and productivity. SO_2 is one of dominant trace gases in the world. What role it plays in the global warming is a subject under study. Theoretically, a mist suspending in troposphere and composed of sulphate particles formed from SO_2 and other particles would weaken radiation from the Sun and alleviate consequence of greenhouse effect. But we are more interested in effect of SO_2-polluted air on insect-plant interaction.

Since Hughes *et al.* (1982) demonstrated that the Mexican bean beetle grew better on soybean leaves which had been fumigated with SO_2, similar response to the air pollutant has been testified in 12 species of phytophagous insects, among them 11 species are aphids (Dohmen, 1984; 1985; Warrington, 1987; 1990; Houlden, 1990; Holopainen, 1991) and another one is the army worm (wu, 1990). The results of present experiment showed that larvae of the turnip moth performed better on rape leaves prefumigated with low levels of SO_2 than on control larvae, and added a more species of insect to the list of phytophagous insects who benefit from the air pollutant.

The reason for improved growth of insects on polluted host plant has not been established, but there are several possible explanations. Braun *et al.* (1984) proposed that reduced numbers of predators and parasites would be responsible. Obviously, this does not hold true for the present results since it was conducted in laboratory. It has been reported that SO_2 exposure altered nitrogen, especially amino acid content in plants (Dohmen, 1984; Wu, 1990). This change in nutrients will often have some substantial effect on insects feeding these plants (McNeill, 1978). Another possibility may be disorder of plant defence mechanisms, including variations in primary nutrients and secondary metabolites (Dohmen, 1985). The latter two hypotheses are

over lapping and likely reasonable for our results since S content in rape leaves increased a lot after exposed to SO_2 (Table 1). It is quite possible that this elements entered the leaves had participated in normal metabolism of the plant and had been incorporated into some S-containing amino acids, for example, methionine. If it is true, this behavior of S-element would disturb the finely balanced relationship that had evolved between insect and plant with benefits to the insect.

Effect of SO_2 pollution on insect should not be ignored, because current concentration of the pollutant usually does not produce easily recognized effect on plant, but is enough to alter the host-insect relationship in such a way that insect growth is greatly enhanced. Insect pests are characterized by fast development and great fecundity with several generations per year. Any small increase in its growth rate could lead to their severer infection. For example, in the east of London, soybean plant are now hard to find due to frequent outbreak of the black aphid induced by SO_2 pollution (Dohmen, 1985).

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