

5.2 Effect on Vegetation

5.2.1 Introduction

In terms of the damage to plants caused by air pollution, it was observed that forests were damaged and agricultural areas showed worsened growth and yield. This was caused by the sulfur dioxide (SO₂) and hydrogen fluoride (HF) from nearby stationary sources. Plant damage was also observed resulting from mobile sources including automobiles which were spurred by the crowded of populations in cities. This plant damage was caused by photochemical oxidants, originating from nitrogen dioxide and hydrocarbon species, etc.

5.2.2 Expressions of visible plant damage

Plant damage resulting from air pollution largely entails the visible damage on leaf surfaces, etc. Table 5.2.1 lists each type of pollutant that causes visible damage. It also presents the threshold concentration of these gases which induce the visible damage. Fig.5.2.1 also divides characteristics of the visible damage into four types and different levels caused by pollutant gases are expressed by+figures. Photographs of examples of damage are also presented.

Table 5.2.1 Apparent symptoms of acute damage of plants caused by air pollutants and threshold concentration at which damage developed

Air pollutants	Thresholds value at which acute symptoms developed	Main symptoms
Sulfur Dioxide (SO ₂)	0.1 - 1.5 ppm	Random spots between leaf veins, brownish-yellow spots on the marginal areas of the leaf (broad leaves), browning on tip or mid-section (coniferous leaves), general spotting
Nitrogen Dioxide (NO ₂)	10 - 50 ppm	Similar to effects of sulfur dioxide
Ozone (O ₃)	0.05 - 0.2 ppm	White or brown spots spread evenly over leaf surface, necrosis, leaves falling prematurely, leaf curvature
PAN	0.05 ppm	Large silver or bronze spots on leaf surface (forming a horizontal band across the entire leaf surface)
Ethylene (CH ₂ =CH ₂)	0.05 - 1.0 ppm	Epinasty of leaf blade, abnormal blooming (pistil degeneration, change from male to female flower, etc.), premature fruit falling, premature defoliation, enhanced yellowing
Hydrogen Fluoride (HF)	5 - 10 ppb	Chlorosis at leaf tip and leaf margin, necrosis
Chlorine (Cl ₂)	0.1 - 0.3 ppm	Chlorotic spots between leaf veins, yellowing of leaf tip

The dose response relation, the relationship between concentration of gases and period of exposure in regards to the visible damage stated above, is presented in inverse proportions. One factor which decides the plant's resistance to visible damage is the plant's absorbency. Fig.5.2.2 lists SO₂ absorption capacity on the abscissa and the corresponding level of apparent damage on the vertical axle. The graph reveals that higher absorbency corresponds to a plant being more easily damaged.

Symptoms of Damage				
	(Yellowing to browning of leaf tip and leaf margin)	(Spots between leaf veins)	(Small spots on leaf surface)	(Shininess of abaxial leaf surface change in color: silver gray~bronzing)
Pollutant type				
Hydrogen Fluoride	++	+		
Chlorine	++	+	+	
Ozone		+	++	
PAN		+		++
Sulfur Dioxide		++	+	
Sulfuric Acid Mist	+	+	++	(++ observed frequently)
Nitrogen Dioxide		++	+	(+ observed sometimes)

Fig. 5.2.1 Characteristics of symptoms of visible damage plant leaves by air pollutants (Yamazoe, 1975)

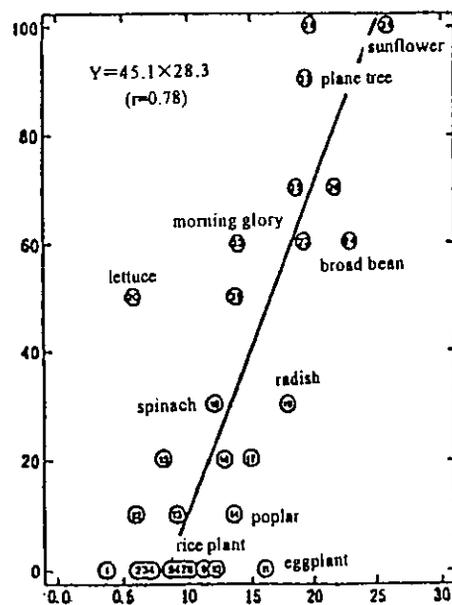
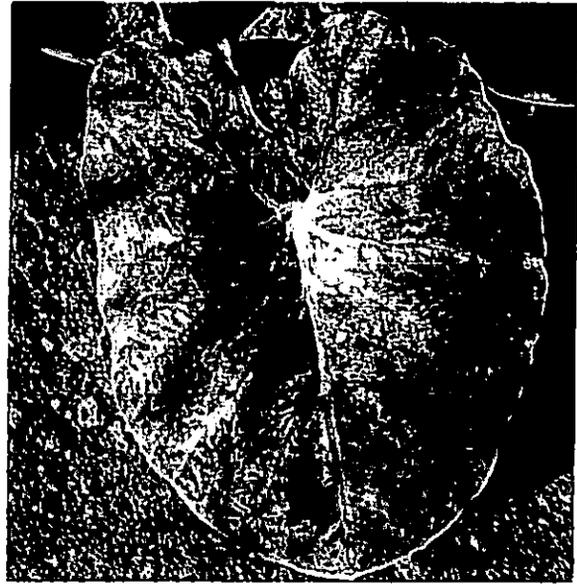


Fig. 5.2.2 The relationship between amount of SO₂ absorbed on leaf surface by SO₂ exposure and level of visible damage on leaf surface (Furukawa et al, 1980)



Foliar injury by ozone in morning glory.
Upper; control, Lower; injured leaf.

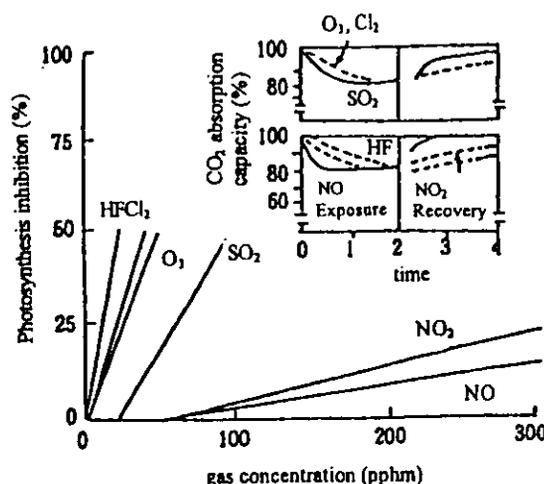
Foliar injury by ozone in taro (upper) and spinach (lower).

Photo.5.1 Apparent symptoms of leaf damage caused by Ozon

5.2.3 The effect on plant's physiological function and yield

Although visible damage usually appears after short term exposure to high concentrations of pollutant gases, plant's fundamental physiological functions including photosynthesis, respiration, transpiration, etc., are affected and plant development stunted by long term exposure to low concentrations of pollutant gases as well.

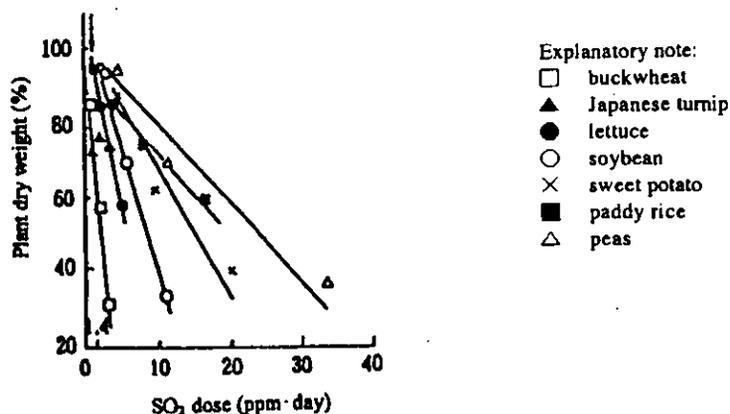
Photosynthesis is particularly sensitive to pollutant gases and is affected even by extremely low concentrations. Results of the effects of various gases on photosynthesis are presented in Fig.5.2.3. Level of photosynthesis inhibition is presented as a relative value (%) to the control on the ordinate. In the Figure lines with the greater slope show more sensitive, revealing the strength of the poisonous effects of these gases. Hydrogen fluoride (HF) is most toxic followed by gaseous chlorine (Cl_2), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). is most toxic followed by gaseous chlorine (Cl_2), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2).



Note: 2 hour exposure for each pollutant gas concentration

Fig. 5.2.3 Effect of pollutant gas on the canopy net photosynthesis of barley and oats (Bennett and Hill, 1974)

When plant's photosynthesis is inhibited, the dry weight growth is affected adversely thereafter. Fig.5.2.4 presents the effect of sulfur dioxide exposure on dry weight growth of several crop plants (concentration ranging from 0.065 to 0.26 ppm, refer to Table.5.2.2). The abscissa plots the gas concentration times number of days of gas exposure (this is referred to as dose). Also, the ordinate presents the relative dry weight of plants as compared to control values. The more the figure line slopes the higher the plant's sensitivity. Also, the smaller the dose at which relative dry weight growth begins to be affected the greater the sensitivity of the plant. In the figures, buckwheat plants has the highest sensitivity. In Fig.5.2.4, line drawn in parallel with the 100% dry weight of the plant the SO_2 dose at the point of intersection with each related line is $1.4 \text{ ppm} \times \text{days}$. Therefore, this value presents the dose limit at which these plants are affected. For instance, if the concentration of SO_2 in the air is 0.02 ppm, the number of days of exposure at which there would be no effect would be $1.4 \div 0.02 = 70$ days. Thus, crop plants harvested within around 70 days would not be affected by the concentrations of 0.02 ppm. Adversely, threshold SO_2 concentration for plants requiring 100 days of growth periods would be 0.014 ppm. Table 5.2.3 presents data for pollutant gases other than SO_2 .



Source: after Fujiwara (1975). (Adapted by Totsuka, 1979)

Fig. 5.2.4 The relationship between SO₂ dose on several crops and the dry weight growth of plant weight (% to a control value).

Table 5.2.2 SO₂ exposure conditions for the crops applied in Fig. 5.2.4.

Species name	exposure time (days)	SO ₂ concentration (ppm)	plant material measured
paddy rice	66	0.065-0.26	dry weight of whole plant
sweet potato	77	0.065-0.26	dry weight of whole plant
soybean	42	0.065-0.26	dry weight of aerial parts
peas	112	0.05-0.3	dry weight of aerial parts
Japanese turnip	14	0.065-0.26	dry weight of whole plant
lettuce	20	0.065-0.26	dry weight of whole plant
buckwheat	13	0.065-0.26	dry weight of whole plant

Source: Totsuka (1979), after Fujiwara (1975)

Table 5.2.3 Concentration threshold value for each gas pollutant causing growth damage

Threshold value concentration of NO ₂	Exposure period	Damage	Plant name	Reference
0.068 ppm	56~140 days	Smaller leaf area and decrease of plant dry weight	Kentucky blue grass	Ashenden (1979)
0.15~0.26 ppm	10~22 days	Reduced leaf area and decrease of plant dry weight	Tomato	Taylor and Eaton (1966)

Threshold value concentration of O ₃	Exposure time	Rate of inhibition	Plant	Reference
0.04 ppm	During entire growth period	Approximately 15% reduction in weight of rough rice	Paddy rice	Plant Environmental Research Institute (1981)
0.05 ppm	During entire growth period	0.05 ppm day/0.025 ppm night 23% less in yield	Paddy rice (Shinsenbon, medium rice)	(Chugoku Agric Inst. Soil Nutn. Lab.) (1981)
0.05 ppm	8hrs./day × 22 days	Growth inhibition (growth in middle)	Tomato(eiju)	Nat. Inst. (1981)
0.05ppm	8hrs./day × 26 days	Growth inhibition (leaf and root) thinning of leaf	Cucumber (tokiwa No.3 P)	

Threshold value concentration of PAN	Exposure time	Damage	Plant	Reference
0.003 ppm	16 months	Root growth, defoliation, concentration estimated by Matusoka	Navel orange	Thompson and Kats

Threshold value concentration of HF	Exposure time	Damage	Plant	Reference
2~3 ppb	13~26 months	Reduction of trunk diameter, tree height, width of branch, trunk volume and leaf surface, decrease of amount of fruit and particularly, 25%~35% reduction in leaf surface.	Navel orange	Brewer et al. (1960)
2.5 ppb	Until harvest	Reduced amount of fruit and seeds	4 types of kidney bean	PACK (1971)
0.7 ppb	43 days	25% reduction in wet weight of bean	Kidney bean	Maclean et al. (1969)