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Article

Investigation of Plant Injury under Ambient Air Pollutants

Jong-Sik Lee,* Joung-Du Shin, Jin-Ho Kim, Goo-Bok Jung, Won-Il Kim, and Gun-Yeob Kim

National Institute of Agricultural Science and Technology, RDA, Suwon 441-707, Korea

In order to find out the cause of plant injury, the symptom of plant injury, and contents of element concerned in the plant were analysed. Also, a case study was conducted to find out the factor of plant injury at a agriculture and industry complex in Gyeongsang province in 2004. The distribution of isomeric curve was made with meteorological data, toxic gas concentration exhausted from pollution source. The general symptom of plant injury by ammonia gas was dry and dead of leaves with white color. At low concentration of ammonia gas, plant leaf showed spots of reddish brown. The characteristic of plant injury symptom by hydrogen fluoride gas was that the symptom was appeared at the edge of leaf. The isomeric curve of sulfur dioxide at the region, where the plant was damaged, showed that the area was affected by exhausted gas from the pollution source. Especially, this area was affected more deeply at summer than any other season.

Key words : Pollution, Plant injury, Ammonia, Hydrogen fluoride, Sulfur dioxide

Introduction

All kinds of gases are emitted into the atmosphere by artificial factors or naturally. In natural factors, there are non-biotic sources such as volcanoes, forest fires, earthquakes, lighting and dust. Artificial ones are mainly comes from the industry and energy using by human life(Volker, 1988). These toxic gases in the atmosphere affect to animal and plant growth, and human health. However, it is difficult to find out pollution source due to its diversity. The amounts of air pollutants, which were emitted into the air, have been increased with increasing of fossil fuel consumption due to industrialization and urbanization. Recently, it is feared that the generation of the secondary pollutants such ozone and PAN have been increased(Kim et al., 1998). Air pollutants seep into the plant through stoma or adsorb on the leaf surface with rain or fog. Then plants are disturbed photosynthesis, hindered growth and blighted by them. (Yang and Lee, 2001).

Regarding to the classification of plant injury types, it is distinguished as visible or nonvisible according to the possibility of macrography, and the former is divided into acute, chronic and intermixture form of plant injury. The acute form of plant injury is appeared to be damaged in short time for high concentration of pollutants. In the other hand, its chronic form is occurred the symptom of chlorosis and growth delay for contacting with the relatively low concentration of pollutants through plant growing periods. However, its non-macrography is to be occurred by the secondly pollution such as growth delay and pest diseases through physiological damage even if not seen the injury symptom of macrography for contacting with the long term in the low concentration of pollutants. There are several factors, which affect plant injury by air pollutants, such as type and concentration of pollutants with the exception of contacting time and periods, morphology, pressure, an air current, temperature, plant species and variety, and growing stages. Also, plant injury by air pollutants was more affected by several intermixture forms than single one(Kim et al., 1989; Kwon et al., 1998).

With enhancement of desire for the optimum environment with pursuit of well-being life, there is recently increasing the concern about safety of agricultural products as well as recognizing the air pollutants in the agricultural environment. Therefore, objective of this study was to investigate the cause of plant damage with injury symptom and analysis of major compounds in plants injured, and diffusion model of pollutants using meteorological data and concentration of emission gas.

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*Corresponding author: Phone : +82312900218,
E-mail : jongslee@rda.go.kr

Materials and Methods

To find out the cause of plant damage by toxic gases in the field, injury symptom with macrography was investigated. The contents of chemical compounds in the plant damaged by toxic gases were measured. Also, a case study was conducted to find out the factor of plant injury at a agriculture and industry complex in Gyeongsang province in 2004. The diffusion model Air Master (Enitech, Korea) was used for determining the atmosphere diffusion of pollutants from its origin. This model can estimate the diffusion of gases emitted with a diagram function of isomeric curve. For this model, we got the data such as meteorological data at investigation area and concentration of toxic gas emitted from the source. It is using a diffusion theory as same as ISC3 (Industrial Source Complex Model-3) model to be recommended by US EPA. The symptoms of crop injury by toxic gases were surveyed from its location. The cause of crop injury with sulfurous acid gas was investigated by diffusion of air pollutants at each season. For chemical analysis, the difference of concentration of pollutant compound between the control and injured plant was evaluated. Cations in the plant analyzed by ICP (Integr XMP, GBC) after post treatment of ternary solution. The contents of sulfur and fluorine were conducted by digestion method of $Mg(NO_3)_2$ and E.C.R (Eriochrome Cyanine R) method (RDA, 2003), respectively.

Results and Discussions

Investigation of plant injury symptom by toxic gases

As characteristics of plant injury by air pollutants, its symptom was mainly occurred on the leaf as it was affected through the stoma in case of gas injury. However, pest disease affected generally on both leaf and steam. Also, physiological disturbance is generally occurred at both new leaf and nutrient deficiency part according to growth stage, but there was priority to be occurred in the growth activated leaf at the same plant in case of gas injury. The light is not affected to the physiological disturbance, but gas injury is greatly affected to the exposed part by light(Kim et al., 1998). The effect of anabolism did not affected to pest injury, and its physiological disturbance greatly by a weak anabolism plant. However, its gas injury was seriously affected to the activated part of anabolism as well as effect of light. The symptom of ammonia gas in the main crops shown in Figure 1. The main emission factors of ammonia are livestock, the urea manufactory plant, cold storage plant, municipal waste management plant and emission gas from automobiles. Crop injury is recently increasing according to the application of undigested manure or overuse of fertilizer nitrogen in the closed space, where the plants are cultivated under structure. It is much occurred at spring and summer because of application of livestock manure and urea fertilizer, and rising in temperature. Crop injury by ammonia gas was first reported in 1896, which through a gas leak around manufactor, and then began to start its study by Garber in 1935 (Fangmeier et al., 1994). Symptom of plant injury shown that plant was blighted from the vertical leaf, and then was dead. It was priority to be appeared as a reddish brown spot on the leaf with exposure of low concentration of ammonia gas. Yang and Lee(2001) demonstrated that the plant root was turned into the black colour, and the stem had the concave form.

For the characteristics of crop injury by air pollutants according to the different plant species and variety, it shown that the symptom of pest disease was occurred in the specific species and variety, but plant injury by gas overall occurred irrespective of them. The symptom of ornamental plant injuries by toxic gas was shown in Fig. 2. Ornamental plant injury by ammonia gas was seriously appeared in the leaf relative to the flower. It decided that air pollutant might be permeated into the internal plant

Fig. 1. Symptom of plant injury by NH_3 gas(left : rice, middle : soybean, right : cucumber).

Fig. 2. Symptom of flowering plants injuries by NH_3 gas.

through the stoma on the leaf (Yang and Lee, 2001)

Fluorine (F) is highly reactive, so it exists as the compound combined with a different chemical element, not single molecule, in the natural world. It is produced from a refinery process, manufacture of phosphorus fertilizer, aluminum processing plant, petroleum refinery plant, and so on (Kockum et al., 2006; Kim et al., 1989). The symptom of rice plant and a gingko tree damaged by fluorine gas was appeared in Fig. 3. An ingredient of fluorine compound in the atmosphere has diversity, and hydrogen fluorine(HF) gas is toxic to the plant(Kim et al., 1989). The main HF emission source are a non-metal refinery, the ceramic and cement manufacture, and also the acid treatment of phosphate rock(Dunham, 1971). HF is become a fluorosilicic acid that combined with the silicic acid during ascending through transpiration, with forming hydrogen fluorine acid in the internal plant. It is easily combined with the silicic acid and accumulated in a vertical hem. Therefore, it is practicing for good indicator of air pollutant that it appeared at vertical or margin of leaf for the symptom of plant injury(Yang and Lee, 2001). It is known that symptom of crop injury by sulfurous acid gas generally had many spot of a reddish brown color at a vein of leaf.(Kim and Han, 1978; Kim et al., 1998).

Investigation of toxic gas injury according to the chemical analysis of plant It is impossible to immediately measure the concentration of air pollutant when symptom of crop injury occurred because its symptom appeared after certain time passed for crop injury by toxic gas. So it is necessary for investigation the cause of plant injury according to the chemical analysis of the toxic compounds in the plant leaf as well as to observe its injury symptom.

For the characteristics of easily combined with silicic acid, fluorine to be permeated into the internal plant part is accumulated in the margin of the leaf (Kim et al., 1989). Therefore, it is very important factor for investigating the cause of plant injury by measuring the fluorine concentration in plant leaf with observing the macrography symptom. The differences of fluorine content in the plant leaf between non-injured and injured areas are shown in Fig. 4. It was shown that the fluorine

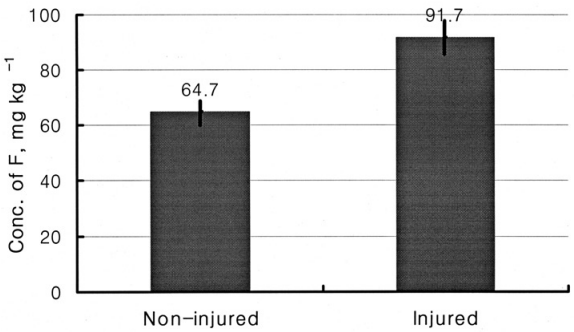

Fig. 4. Concentration of F in leaf of rice plant.

Fig. 3. Symptom of plant injury by HF gas. (left : rice plant, right : gingko tree).

accumulation in injured rice leaf, 91.7 mg kg^{-1}, was greater than that of uninjured one, 64.7 mg kg^{-1}.

Investigation of toxic gas injury by using diffusion model of air pollutants Sometime, it is very difficult to estimate whether the crop got injured or not through analysis of chemical compound in the plant, because investigation of crop injury with air pollutant is conducted after passing much time from it happened. Therefore, the possibility of crop injury is estimated with diffusion of air pollutant by using meteorological data at investigation area and concentration of toxic gas emitted from the source. A case study was conducted to find out the factor of plant injury. The location which had a crop injury was hilly sloped district, and could be diffused through the slop. And the pollution source emitted SOx of 112 ppm. Based on its emission concentration and meteorological data, the isomeric curve of sulfur dioxides at investigation area at each season were described in Fig 5. It showed that investigation area is affected by sulfurous acid gas from the emission source, and concerned about crop injury in the summer according to the isomeric curve.

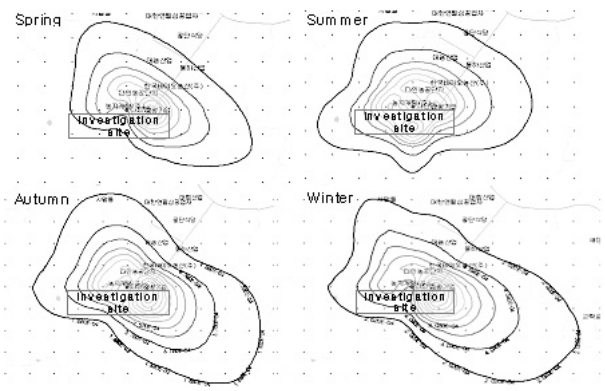

Fig. 5. Seasonal isomeric curve for SO_2 in investigation area, where fruit trees were damaged.

Conclusions

Toxic gases, which are emitted into the atmosphere affect to plant growth. However, it is very difficult to find out the cause of plant damage, because the crop injury is generated after passing times from it happened. In this study, the symptom of plant injury, distribution of isomeric curve of gas exhausted from pollution source, and contents of element concerned in the plant were analysed.

As the results, the investigation for finding out the cause of plant injury are needed several steps. In the field survey, observation of symptom of plant damaged and data collection such as topography, meteorology at its location and concentration of toxic gas emitted from the source are required. It is also needed that chemical element concerned in the plant are analysed. On the other hand, the diffusion model, which can estimate the diffusion of gases emitted with a diagram function of isomeric curve are useful for determining the atmosphere diffusion of pollutants from its origin.

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대기오염물질에 의한 농작물 피해원인 조사

이종식* · **신중두** · **김진호** · **정구복** · **김원일** · **김건엽**

농업과학기술원 환경생태과

농작물 안전생산 및 대기환경 개선을 위한 기초 자료로 활용하기 위하여 유해가스에 의한 농작물 피해원인을 구명하였다. 작물 피해현지에서 유해가스에 의한 피해증상을 조사하였으며, 작물체중 유해성분 함량을 분석하였다. 또한, 2004년 경북지역 농공단지에서 발생한 작물피해 사례에 대한 피해원인 구명을 위하여 조사지역의 피해발생 당시 기상자료 및 오염원에서의 배출가스 농도를 적용한 오염물질 확산을 제시하였다.

주요 작물의 암모니아가스 피해증상은 잎 끝으로부터 백색으로 고사하며, 저농도의 경우에는 적갈색 반점이 나타나는 특징을 보였고 화훼류의 경우에는 꽃보다 잎의 피해가 심하게 나타났다. 불소가스 피해증상은 잎의 선단이나 가장자리 부분에 나타나는 특성이 있다. 또한, 유해가스로 인한 작물피해 현지 사례에서 피해 지역의 아황산가스 등농도(等濃度) 분포를 조사한 결과, 조사지역은 발생원으로부터 발생된 아황산가스 영향을 받고 있으며, 특히 계절별로는 기상요인에 따른 여름철의 피해가 우려되었다.