Effect of Sulfur Dioxide and Hydrogen Fluoride on Rice Plant Growth in Industrial Estate

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工業團地周邊에서의 亞黃酸가스 및 弗化水素가 水稻 生育에 미치는 影響

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ABSTRACT : The study was performed to investigate the effects of gaseous emission of sulfur dioxide and hydrogen fluoride on the growth of rice plant under stressed field conditions. This study is specifically dealt with multiple effects of sulfur dioxide and hydrogen fluoride on various plant growth indicators such as leaf damage, weight of grain, panicles per hill, spikelets per panicle and percent fertility.

It appears that there is a good correlation between ambient concentrations of sulfur oxides and sulfur contents found in leaves with an average correlation coefficient of 0.868 within a 1% significance level. A better multiple correlation was found between percent leaf damage and sulfur and fluorine contents found in leaf with a significance of 1% level. The correlation coefficient ranges from 0.807 to 0.978 with an average being 0.922.

An evaluation of data observed has demonstrated that both panicles per hill and percent fertility are significantly affected by air pollutants. As expected, hydrogen fluorides have more effects than sulfur oxides. It is, however, interesting to note that spikelets per panicle has slightly been affected while no indication of effects on 1000-grain weight has been observed. This may lead to a conclusion that a reduction in yield of rice under polluted field conditions may have more been caused by the diminution panicles per hill and percent fertility rather than by the diminution of spikelets per panicle and grain weight.

INTRODUCTION

The effect of atmospheric sulfur dioxide and hydrogen fluoride on rice plants have well-documented during the past several decades and have been the subject of several recent reported studies. [1,2,5,6,7,8,9,11] These studies were conducted to examine effect of a single pollutant on the plant, either by sulfur dioxide[6,7] or by hydrogen fluoride[4] under field conditions. A number of studies has also been performed to investigate a dose-response relation of a single air pollutant in a simulated exposure chamber.

The study is designed to evaluate the multiple effects of sulfur dioxide and hydrogen fluoride under field conditions on various plant growth indicators such as leaf damage, weight of grain, panicles per hill, spikelets per panicle and percent fertility. The objectives of this investigation is to analyze the interrelationships between these factors, thus finding which factor(s) is playing the major role to the reduction in yield, how it affects and reasonable explanation of how these factors are being incorporated to lead ultimate yield reductions.

The Ulsan Industrial Estate is chosen for this investigation because there are 88 big industrial plants operating with 285 smoke stacks emitting various gaseous pollutants with sulfur compounds and hydrogen fluoride being the most important. Also the estate is the biggest and the oldest industrial complex ever

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established in country.

MATERIALS AND METHODS

Shown in figure 1 are the location of selected industries, sampling sites and the areas(shade) where the damages have been reported. Sampling sites No 1 through No 18 are located near the rice paddies where the damages has occured whereas the sites No 19, 20 and 21 are selected as controls. Seleted industries are those that are emitting more than 120tons SO2 per year and the ones that are emitting hydrogen fluoride regardless the amount of pollutant. The annual rate of emission for each source ranges from 0.62 to 98,781 ton for sulfur dioxide and from 3.03 to 210.15 ton for hydrogen fluoride. The total annual emissions are 176,500 tons for sulfur dioxide and 415 tons for hydrogen fluoride, respectively.[3,4]

Figure 2 illustrates sampling schedules for air pollutant concentrations and various growth factors. As for sulfur/fluorine contents in leaves, periodical samples are collected at intervals of a month from July to September each year for four years. This is done on selected 30 hills per sites for ensuring statistical confidence. For yield characters such as panicles per hill, spikelets per panicle, 1000-grain weight and percent fertility, an intensive samples are taken are measured at havesting stage. Leaf damages are checked five different times (June 19, July 2, 16, August 2, 16 every year) on top four leaves because there are the most active normal leaves from the phytophysiological point of view. And Nak-Dong was selected to perform the experiment.

RESULTS AND DISCUSSION

Listed in the table-1 are the relationships between the pollution factors which are believed to affect the growth of rice plants and subseqently the overall rate of yields. It is observed that there is a good correlation between ambient air concentrations of sulfur dioxids and sulfur contents measured in leaves with an average correlation coefficient being 0.831 at a 1% significance level. More significantly a better multi-

Table 1. Correlation coefficients between pollution factors

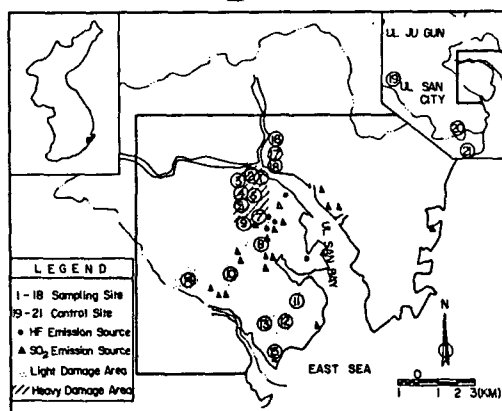| Factor | Range | | Mean | Significance level |
	Min.	Max.		
SO3-S	0.713	- 0.910	0.831	1%
SO3-%D	0.133	-0.658	0.307	NS
S -%D	0.029	- 0.678	0.373	NS
F -%D	0.799	- 0.980	0.917	1%
S+F-%D	0.807	- 0.978	0.922	1%

Fig. 1. Sampling sites

ple correlation is found between percent leaf damage (%D) and sulfur and fluorine contents in leaves ; the average coefficient being 0.992 with a significance at the 1% level. This may lead us to believe that the percent leaf damage may serve as the single most important index of air pollution damages to rice plant cultivating in polluted atmosphere in fields.[1,10,11]

Fluorine contents observed in leaf is proved to be closely correlated to percent leaf damage with an average correlation coefficient being 0.917 at the 1% significance level whereas no significant correlation is found either between sulfur contents in leaves and leaf damage or between atmospheric sulfur and leaf damage ; correlation coefficients being 0.373 and 0.307, respectively.

As for the relationships between yields and yield characters it is proved that the panicles per hill (P/H) is the single most important character affecting the rate of yield of rice plant as shown in figure 3. The largest average correlation coefficient is found with panicles per hill with a significance at the 1% level throughout the course of this investigation (4 years) ;
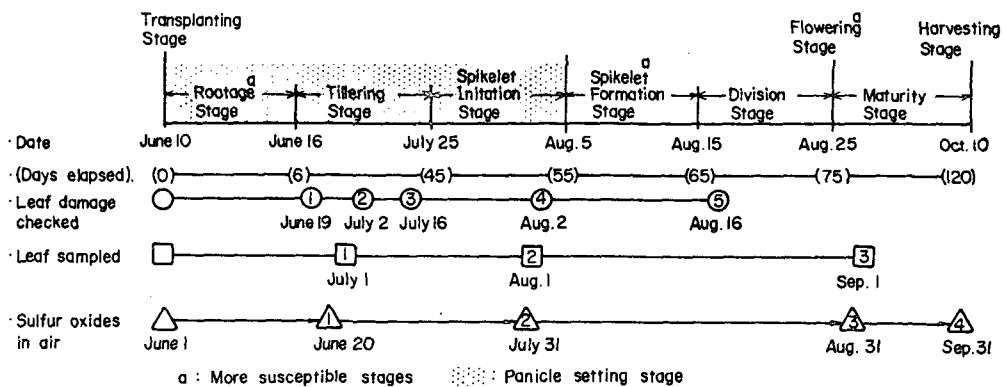
Fig. 2. Growth stages of rice plant and date checked of growth characteristics and of pollution factors.

P/H : Panicles / Hill   ( ) : Percent contribution
S/P : Spikelets / Panicle   a : Significance at the 1% level
%F : Percent Fertility   b : Significance at the 5% level
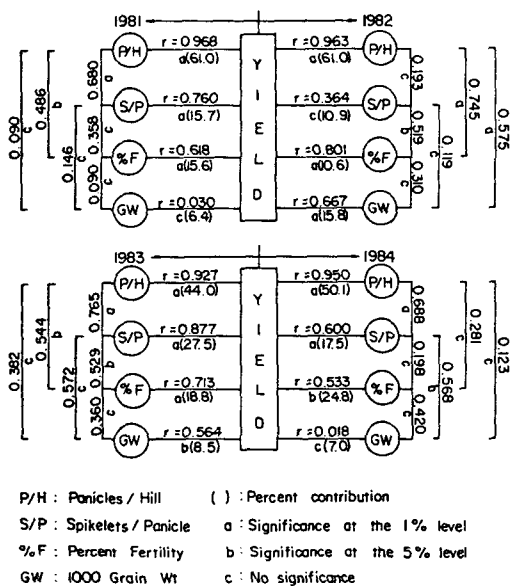GW : 1000 Grain Wt   c : No significance

Fig. 3. Diagramatic expression of path analysis
between yield and its characteristic.

the value being 0.952. Based on the standard partial regression coefficient analyses, P/H has the largest contribution to the yields and the average percent contribution is 54%.[6,12] Other characters such as spikelets per panicle(S/P), percent fertility(% F) and 1000-grain weight(G W) are also contributing to the yield and their contributions are far less. Given the fact that the panicles per hill is mainly governed during the initial stage of the rice plant as shown in the figure 2, it would be critical in terms of yield if the plants are exposed to severe pollutions during this early stage.

Listed on the table 3 are correlation coefficients between the pollutional factors and yields and yield characters.

As can be seen clearly in table 3, no significant correlation is observed between sulfur contents in leaves and yield, P/H, S/P, % F or G W while a good correlation is demonstrated between yields and the fluorine contents in leaves with the average coefficent being 0.842 at the 1% significance level. It is also interesting to note that the leaf fluorine content has a significant correlation with all yield characters with the exception of 1000-grain weights. No correlation seems to exist between 1000-grain weights. No correlation seems to exist between 1000-grain weights and pollution factors, as were the cases reported in literatures.[1,6,7,8,9]

CONCLUSIONS

Summarizing the study, the following conclusions can be drawn :

1) A strong correlation exists between ambient sulfur oxide concentration and sulfur contents in leaf.

2) Percent leaf damage may serve as the single most important pollutional index to yield reduction of rice plants cultivating in polluted fields.

3) Under the field circumstances of this study fluorine plays major role in leaf damage in spite of the fact that the annual emission of sulfur is considerably larger than that of fluorine.

4) It is proved that panicles per hill has major

Table 3. Correlation coefficient between factors and yield/yield characteristics.

Factor	RANGE			Mean	Significance level
	Min.		Max.		
S – Y	0.128	~	0.769	0.467	NS
F – Y	0.557	~	0.945	0.842	1 %
%D – Y	0.667	~	0.943	0.877	1 %
S – P/H	0.049	~	0.705	0.393	NS
F – S/P	0.059	~	0.830	0.513	5 %
%D – S/P	0.035	~	0.806	0.488	5 %
S – % F	0.009	~	0.518	0.255	NS
F – % F	0.397	~	0.819	0.620	1 %
%D – % F	0.416	~	0.710	0.616	1 %
S – G W	0.002	~	0.406	0.222	NS
F – G W	0.062	~	0.490	0.317	NS
%D – G W	0.133	~	0.538	0.333	NS

S   : Sulfur in leaf
% D : Percent leaf damage
P/H : Panicles/hill
% F : Percent fertility

F   : Fluorine in leaf
Y   : Yield
S/P : Spikelets/panicle
G W : 1000-grain weight

effects on the yield of rice plants. The panicles per hill has strong affinity with fluorine contents in leaf.

5) No significant relationship is found between sulfur contents in leaf and yields/yield characteristics.

摘　　要

多量의 大氣汚染物(SO2, HF)이 排出되고 있는 工業團地 周邊에서 栽培되고 있는 水稻의 生育에 이들 大氣汚染物이 미치는 影響을 究明하기 위하여 水稻의 各種 形質, 收量, 大氣中의 汚染物 濃度, 葉內硫黃 및 弗素含量과 葉被害率을 調査하여 檢討한 結果는 다음과 같다.

1. 葉內硫黃含量과 大氣中의 亞黃酸가스 濃度間에는 높은 正의 相關이 認定되었다.

2. 葉被害率 調査値는 大氣汚染에 의한 收量減少의 가장 重要한 指標로 이용 할수 있다.

3. 本 調査地域에서는 亞黃酸가스보다 弗化水素의 排出量이 적지만 葉被害의 發生에는 弗素의 關聯性이 亞黃酸가스보다 높았다.

4. 收量形質의 收量에 對한 寄與程度는 株當穗數가 제일 컸으며, 株當穗數는 葉內 弗素含量과 깊은 關聯性이 認定되었다.

5. 葉內 硫黃含量은 收量 및 收量形質과 相關性이 認定되지 않았다.

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