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Effects of ground-level ozone (O_3) pollution on the yields of rice and winter wheat in the Yangtze River Delta

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Abstract: Effects of elevated O_3 on the yields of rice and winter wheat were studied by using open-top chambers(OTCs). Results showed that compared to the control treatment, 200 ppb, 100 ppb, 50 ppb treatments caused a 80.4%, 58.6% and 10.5% decrease in grain yields per winter wheat plant and a 49.1%, 26.1% and 8.2% decrease in grain yield per rice plant, respectively. According to the dose-response relation educed from OTCs experiment and the monitor data of O_3 concentrations in spots, it was estimated that the yield losses of rice and winter wheat resulted by O_3 pollution in the Yangtze River Delta region in 1999 were 0.599 million ton and 0.669 million ton, economic losses were 0.539 billion RMB Yuan and 0.936 billion RMB Yuan, respectively.

Keywords: rice; winter wheat; O_3; Yangtze River Delta

Introduction

In China, with the rapid economic development and unprecedented changes in land use, artificial emission of NOx and VOCs has increased significantly to the double during the past 11 years and reaches the same level as USA and Europe (Elliott, 1997). As a result, the ground-level O_3 concentration is increasing at a striking rate. The latest studies showed that ambient O_3 concentration in many rural areas is high enough to reduce crop yield(Chameides, 1999; Jin, 2001). This paper educed the dose-response relation between O_3 concentration and the yield of rice and winter wheat and assessed yield and economical losses of those crops caused by O_3 pollution in Yangtze River Delta region.

1 Effects of O_3 on yields of rice and winter wheat

Field study was carried out by using open top chambers(OTCs). Plants were exposed to 5 O_3 levels included control treatment(carbon filter air, CF), no filter air (NF), 50 ppb, 100 ppb and 200 ppb. Winter wheat(*Tritcium sastivum*, L.) cultivar is Jingdong-6. On 3 October 1998 winter wheat seeds were planted into crock pots. On 3 April 1999 plants were transferred to OTCs and began to expose. On 4 June 1999 exposures stopped. Rice(*Oryza Sativa*, L.) cultivar is Zhongzuo-9321. On 1 May 1999 rice seeds were planted under field condition. Then on 9 June rice seedlings were transplanted to crock pots. Then plants were exposed to O_3 from 4 July to 1 October. The duration of exposures per day is 7 h/d(9:00—16:00).

Decrease in grain yield under O_3 stress was found in Fig.1. Compared to the control treatment, 200 ppb, 100 ppb and 50 ppb, NF treatments caused −80.4%, −58.6% −10.5% and +4.7% decrease respectively in grain yield per winter wheat plant and −49.1%, −26.1%, −8.2% and −7.3% decrease in grain yield per rice plant, respectively. Though no significant change was found less than 50 ppb and NF treatment, 200 ppb and 100 ppb O_3 result to 60.0% and 47.2% decrease respectively in the 1000 grain dry weight of winter wheat, respectively. 200 ppb O_3 caused a 17.0% decrease in the 1000 g dry weigh of rice. Whereas the other treatments did not cause significant changes in the 1000 g dry weight of rice.

2 Assessment of yield and economic losses of rice and winter wheat caused by O_3 pollution in Yangtze River Delta region

According to the results of OTCs experiment mentioned above, remarkable linear relation between the grain yield reduction rate and O_3 dose was established. The equation is as follows: Winter wheat: $y = -1.296x$; Rice: $y = -0.526x$, where, y is the loss rate of yield (%) and x is the AOT40(accumulated exposure over a threshold of 40 ppb, AOT40 = $\sum$ (O_3 − 40 ppb)).

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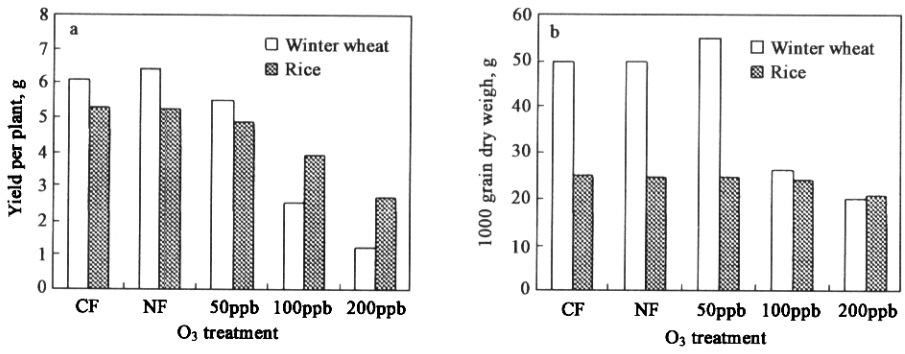

Fig.1 Effects of O_3 on the yields(a) and 1000 g dry weigh(b) of rice and winter wheat plant

According to the dose-response relation mentioned above and the monitor records of O_3 AOT40 in the Yangtze River Delta region(Table 1), the loss rates of crop yield in 6 monitoring points(Sheshan, Changshu, Jianhu, Gourong, Lin'an, Jiaxing) were calculated. Due to the similarity of geography and economical situation of the Yangtze River Delta region, 6 monitoring points represented the different areas in Yangtze River Delta region, respectively. Then the special distribution of loss rate of yield in Yangtze River Delta region was plotted. Fig.2 clearly showed a larger decrease in yield of winter wheat(> 10%, expect Jianhu) and a smaller decrease in yield of rice(< 5%) resulted from O_3 pollution.

Table 1 O_3 dose (AOT40) in the Yangtze River Delta region (ppm/h)

Monitoring points	Sheshan	Changshu	Jianhu	Gourong	Lin'an	Jiaxing
Winter wheat (Apr.-May)	10.362	8.347	—	8.722	7.924	10.559
Rice (Jul.-Sep.)	5.528	6.007	2.700	—	5.376	4.625

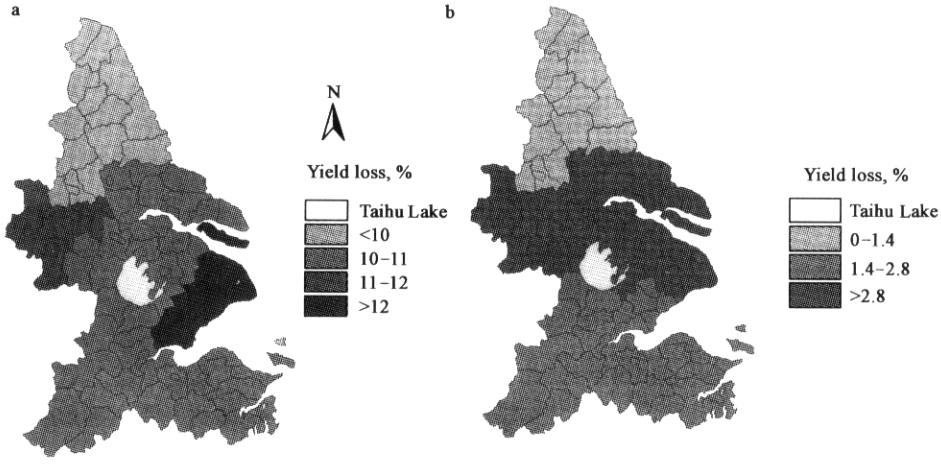

Fig.2 Loss rate (%) of crop yields caused by O_3 pollution in Yangtze River Delta region
(a: winter wheat; b: rice)

The losses of crops yields caused by O_3 pollution in the Yangtze River Delta region was calculated using the formula as follows:

$$y = a \times b/(1-b),$$

where y is the loss of yield, a is the actual crop yield, b is the loss rate of yield. In the formula, $b/(1-b)$ represents the theoretic yield of rice or winter wheat free from O_3 pollution. The direct economic losses were calculated by the losses of yield

multiplying unit price 0.9 RMB Yuan/kg(rice) and 1.4 RMB Yuan/kg(winter wheat). Table 2 shows that the yield and economic losses caused by O_3 pollution in the Yangtze River Delta region in 1999 is 0.599 million ton and 0.539 billion RMB Yuan for rice, 0.669 million ton and 0.936 billion RMB Yuan for winter wheat, respectively.

Table 2 Yield and economic losses of rice and winter wheat caused by O_3 pollution in Yangtze River Delta region in 1999 (Yield, million ton; economic loss, billion RMB Yuan)

Province	City	Rice			Winter wheat		
		Total yield*	Yield loss	Economic loss	Total yield*	Yield loss	Economic loss
	Shanghai	1.591[a)]	0.048	0.043	0.403[a)]	0.063	0.088
Jiangsu	Nanjing	1.250[b)]	0.041	0.037	0.329[b)]	0.042	0.058
	Wuxi	1.070[b)]	0.035	0.032	0.362[b)]	0.044	0.061
	Changzhou	1.188[b)]	0.039	0.035	0.297[b)]	0.036	0.050
	Suzhou	1.695[b)]	0.056	0.050	0.514[b)]	0.062	0.087
	Nantong	1.604[b)]	0.053	0.048	0.811[b)]	0.098	0.137
	Yancheng	2.391[b)]	0.034	0.030	1.441[b)]	0.072	0.101
	Yangzhou	1.625[b)]	0.023	0.021	0.777[b)]	0.039	0.054
	Zhenjiang	0.870[b)]	0.029	0.26	0.299[b)]	0.038	0.053
	Taizhou	1.688[b)]	0.056	0.050	0.914[b)]	0.111	0.155
Zhejiang	Hangzhou	1.265[c)]	0.037	0.033	0.212[c)]	0.024	0.034
	Ningbo	1.504[c)]	0.044	0.039	0.030[c)]	0.003	0.005
	Jiaxing	1.353[c)]	0.034	0.030	0.113[c)]	0.018	0.025
	Huzhou	0.907[c)]	0.026	0.024	0.093[c)]	0.011	0.015
	Shaoxing	1.554[c)]	0.045	0.041	0.079[c)]	0.009	0.013
	Total	21.555	0.600	0.539	6.674	0.668	0.936

* Sources: a) Shanghai Agriculture and Forestry Bureau (ed.), Rural Statistic Yearbook of Shanghai, 2000;
b) Jiangsu Agriculture and Forestry Bureau (ed.), Rural Statistic Yearbook of Jiangsu Province, 2000;
c) Zhejiang Agriculture and Forestry Bureau (ed.), Agricultural Statistic Datum of Zhejiang Province in 1999, 2000

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