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Effects of Air Pollutants on Seed Germinability

Ajoy G. Chakrabarti
Department of Natural Sciences, South Carolina State College, Orangeburg, S. C. 29117

It is now widely known that carbon monoxide, nitrogen dioxide and sulphur dioxide are the three major gaseous substances that pollute the atmosphere. Studies on effects of CO and NO_2 on the germinability of garden pea and string bean seeds were performed. The treatment with NO_2 delayed germination and caused higher death rate of bean seedlings when compared to the treatment with CO (CHAKRABARTI 1976). Nitrogen dioxide inhibited the apparent photosynthesis of alfalfa at concentrations above 0.6 ppm (HILL and BENNETT 1970). The continuous exposure of naval orange trees to 0.5 ppm and 1 ppm of NO_2 for 30 days caused severe defoliation and chlorosis (THOMPSON et. al. 1970). Air polluted with parts 10^{-8} concentration of NO and NO_2 significantly reduced the growth of tomato (Licopersicum esculentum) plants (CAPRON and MANSFIELD 1977). The treatment with $1^g/m^3$ SO_2 applied for 2 hours at an interval of seven days, caused partial chlorosis in some leaves of Hordeum vulgare. Photosynthesis was inhibited and a complete structural destruction of cytoplasm and organelles occurred (COIBANU and COIBANU 1973). Air pollutants affecting metabolic activities within the cell caused anatomical and cytological modifications in paliside parenchyma in corn leaves and thereby causing growth inhibition and partial chlorosis (CIRELI 1976). These evidences strongly suggest that the pollutant gases might influence the germinability of the selected seed species and affect seedling growth.

The objective of this research was to study the effects of a selected concentration of CO, NO_2 and SO_2 on the germinability of wild mustard, pigweed, giant ragweed, cocklebur and soybean seeds.

MATERIALS AND METHODS

One thousand seeds each of cocklebur (Xanthium pennsylvanicum Wallr.), pigweed (Amaranthus retroflexus L.), wild mustard (Brassica Kaber Wh.), giant ragweed (Ambrosia trifida L.) and soybean (Glycine max Var. Bragg.) were distributed evenly on 3 cm thick plots of vermiculite with 250 seeds in each plot. The plot size was about 10 cm x 20 cm each. All plots were placed on a large plastic tray seated on the floor of a chamber walled and roofed by thin, transparent glass. The growth

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chamber was 123 cm long, 50 cm wide, and 58 cm tall. The chamber was a perfect rectangle when viewed from any side. The chamber was equipped with two incandescent tube lights covering the entire length of the glass roof. The actual irradiance received by the plots was 1.5 mw cm^{-2} as measured by a power meter (Model #615 made by Optics Technology, Inc., Palo Alto, California). The plots experienced 12 hours of daily exposure to light. The temperature of the chamber varied from 24^{o}-26^{o} C. The seeds were surface sterilized with 10% commercial Clorox (5.25% sodium hydrochlorite) for 10 minutes and rewashed with distilled water prior to experimentation to control the growth of microorganisms.

The required quantity of pollutant gases was prepared by the known amounts of pure reactants in relation to the fixed volume of the chamber. In the control experiment no pollutant gas was added. The chamber was thus attempted to maintain the laboratory atmosphere. All other treatments maintained an additional 24 ppm of a specific gas. This concentration seemed to be quite applicable for studying effects of pollutant gases on the germination and seedling growth (CHAKRABARTI 1976). Carbon monoxide was prepared by reacting formic acid with an excess amount of sulfuric acid. Nitrogen dioxide was prepared by reacting nitric acid with copper turnings. Sulfur dioxide was prepared by reacting sodium sulfite with sulfuric acid.

Observations on the percent germination, seed death and seedling death were recorded daily. Any other noticeable changes on seedling growth were also recorded.

RESULTS

Seeds treated with pollutant gases had more variable germination results than non-treated controls (Table I, Figure I). No noticeable germination was observed in any seed species by the treatment with SO_2. Only cocklebur seeds germinated by the treatment with NO_2 gas and the germination was only four percent. Highest germination was obtained by the treatment with carbon monoxide in all seed species. Carbon monoxide boosted the germination of wild mustard, pigweed, giant ragweed, cocklebur, and soybean seeds to an increased percentage of 66, 46, 76, 34 and 90 respectively.

The germination period was also affected by the treatment with the pollutant gases. Carbon monoxide increased the germination period in wild mustard, cocklebur, and soybean seeds to 12, 21 and 10 days, whereas the germination period was reduced in pigweed and giant ragweed seeds about 3 and 5 days respectively as compared to the control experiment.

Pollutant gases influenced the death rate of seedlings at various degrees. Carbon monoxide and NO_2 accelerated the death rate of seedlings to almost a uniform degree in all experimental seed species. The death rate of cocklebur seedlings seems to

TABLE I

EFFECTS OF POLLUTANT GASES ON THE INCREASE IN PERCENT GERMINATION PER DAY

	WILD MUSTARD			PIGWEED			GIANT RAGWEED			COCKLEBUR			SOYBEAN		
DAYS:	CONTROL	CO.	NO_2	CONTROL	CO.	NO_2	CONTROL	CO.	NO_2	CONTROL	CO.	NO_2	CONTROL	CO.	NO_2
1	0.0	17.4	0.0	0.0	5.6	0.0	0.2	5.4	0.0	0.8	.6	0.1	0.0	19.9	0.0
2	0.2	41.4		0.5	12.0	0.0	0.3	9.9		2.8	.8	1.3		23.9	
3	0.2	58.8		0.5	28.3	0.0	0.8	20.7		10.1	5.1	1.3		31.3	
4	0.2	62.5		0.7	34.2	0.1	1.0	29.0		12.1	9.6	2.8		44.2	
5		63.6		0.9	38.1		1.0	44.3		13.1	0.9	3.4		66.4	
6		65.0		1.1	40.2		1.0	57.5		13.7	20.2	3.7		82.0	
7		65.5		2.0	41.5		1.0	67.4		14.0	22.0	3.7		87.5	
8		65.6		2.2	42.7		1.6	70.3		16.4	25.3	4.1		88.8	
9		65.7		2.4	43.3		1.6	72.6		16.8	25.8			89.4	
10		65.8		2.4	43.9		1.6	73.3		17.0	27.6			90.3	
11		66.0		2.4	44.4		1.6	74.8		17.0	28.8				
12		66.1		2.9	44.5		1.6	74.9		17.0	29.1				
13		66.1		2.9	44.5		2.3	74.9		17.0	29.8				
14		66.1		2.9	44.9		2.3	74.9		17.2	30.2				
15		66.1		2.9	45.4		2.3	75.0		17.2	31.7				
16		66.1		3.4	45.6		2.3			17.2	31.9				
17		66.1		3.4	45.9		2.3			17.2	32.8				
18		66.3		3.4	46.4		2.3			17.5	33.1				
19				3.4			2.3			17.5	33.7				
20				3.4			2.9			17.6					
21				3.5			2.9			17.6					
22							3.2			18.8					
23										19.4					
24										19.8					

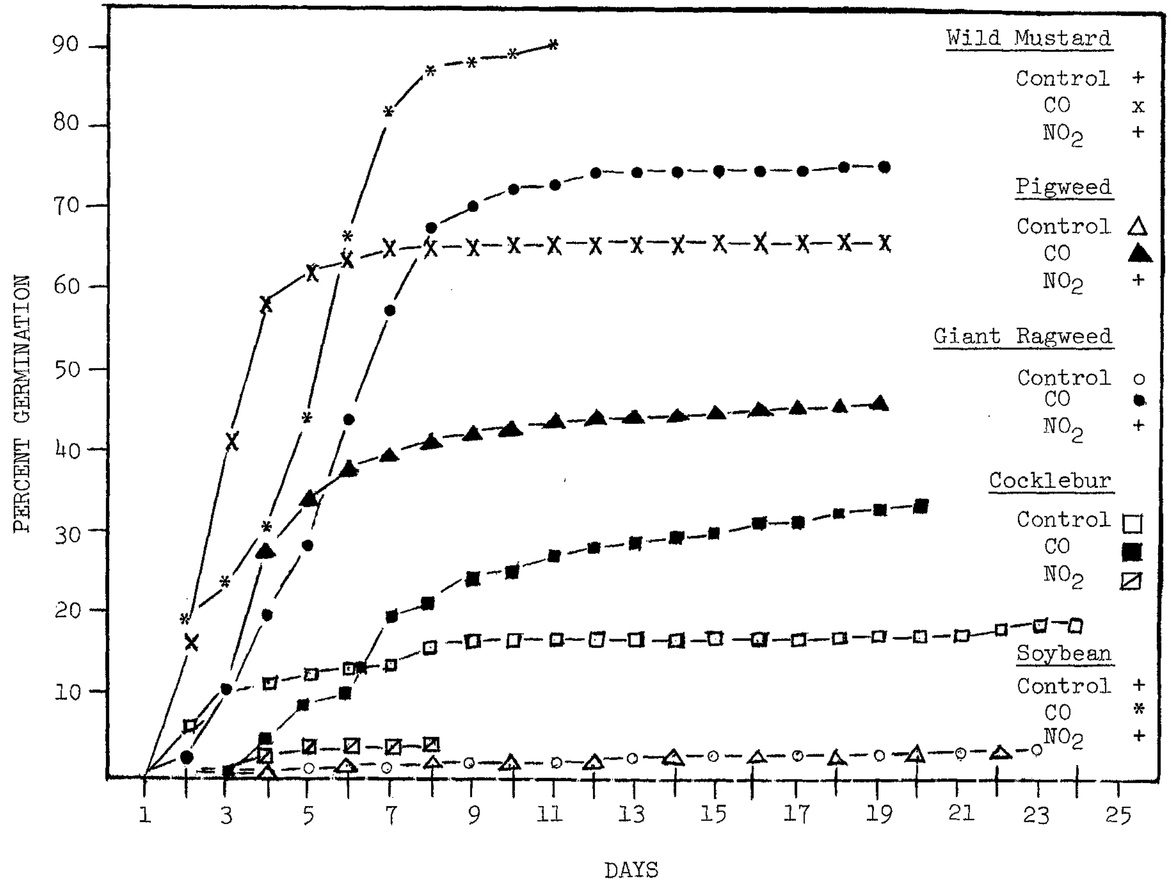

FIG. I. Effects of Carbon Monoxide and Nitrogen Dioxide on the Daily Increase in Percent Germination of Selected Weed Seed Species.

be greater in NO_2 when compared to that of carbon monoxide. The life span for all seedlings of wild mustard, pigweed and soybean species was reduced by 7, 16 and 18 days respectively, whereas the life span of giant ragweed and cocklebur seedlings by 18 and 14 days, respectively by the treatment with carbon monoxide. Nitrogen dioxide reduced the life span of cocklebur seedlings by 30 days as compared to the control (Figure III).

The data on death of seeds was also recorded. Some of the dormant seeds died in all treatments including the control. The drastic seed death was observed by the treatment with SO_2. In fact the sign of decay and death started on the second day of SO_2 treatment and all seeds rotted in a period of one week. Soybean, giant ragweed and wild mustard seeds showed signs of chlorosis, browning, and marginal curling in older leaves. Wild mustard and pigweed seedlings showed signs of death from the apices backward. Stems of wild mustard, pigweed and soybean seedlings showed signs of rotting of older stems and shedding of leaves. These observations were found both in the control experiment and by the treatment with carbon monoxide. Therefore, these effects may be attributed to the mineral deficiencies and other ecological factors rather than the polluted atmosphere of the chamber.

The height of soybean and wild mustard seedlings reached 27 cm and 4 cm, respectively against no germination or seedling growth in the control experiment. The height of seedlings in other treatments did not differ significantly from the control. The plotted and tabulated results represent the average figures from triplicate experiments.

DISCUSSION

From the results it is quite evident that the pollutant gases affected both seed germinability and seedling morphorology to various degrees. Sulfur dioxide applied in 24 ppm inhibited germination and induced rotting of seeds and thus it was found to be very toxic. A high concentration of SO_2 caused structural destruction of cytoplasm and cell organells in some leaves of Hordeum vulgare (COIBANU and COIBANU 1973). A chronic exposure of SO_2 affected the early vegetative growth of soybean (TINGY et. al. 1973). Nitrogen dioxide was also found to be rather toxic since germination was inhibited in all seed species except only 4% germination in cocklebur seeds. The killing effect of nitrogen dioxide on cocklebur seedlings was also found to be much higher as compared to carbon monoxide. An injurious effect of NO_2 was observed on alfalfa at concentration higher than 0.6 ppm (HILL and BENNETT 1970). The growth of tomato plants was significantly reduced by a mixture of NO and NO_2 (CAPRON and MANSFIELD 1977). The appearance of chlorosis and curling of leaves in the polluted atmosphere as observed in this research was also reported in potato plants grown in a polluted atmosphere in a growth chamber (KIRHAM 1974).

Surprisingly, carbon monoxide applied in 24 ppm increased the germinability of all seed species used in this research. The period and percentage of germination were increased by the treatment with CO. Carbon monoxide also increased the life span of giant ragweed and cocklebur seedlings. It is thus difficult to interpret these promoting effects of CO on seed germinability since CO is widely known to be a respiratory inhibitor. When tested on filter paper in petri dish germinators under the same light and temperature conditions as utilized in this research, the percent germination of cocklebur, pigweed, wild mustard, giant ragweed and soybean seedlings was found to be 61.3, 90.3, 79, 11.8 and 91.3 respectively. On the other hand, the percent germination of wild mustard, pigweed, giant ragweed, cocklebur and soybean seeds in the control experiment of glass chamber were 0.2, 3.5, 3.2, 19.8 and 0.0, respectively. The reason for this lower germination as compared to the petri dish environment was probably due to less contact of moisture with seeds on granular vermiculite since the environment was saturated with humidity in both the petri dish and glass chamber. If CO had promoting effects on the process of the imbibition and absorption of water molecules by seeds is unknown at this point. If CO were converted to CO_2 by the oxygen available in the chamber and if this CO_2 were further converted to H_2CO_3 (carbonic acid) by the water molecules available in atmosphere and on seedbed of the chamber is also unknown at this point. If the above hypothesis is correct, probably the pH of the water available in the seedbed was lowered by the H_2CO_3. In another experimental setup for studying the influence of low pH of the water absorbed by some weed seeds kept in petri dish germinators, it was observed that the percent germination of cocklebur seeds increased significantly at pH 4.0, 4.5 and 5.5 as compared to the percent germination of cocklebur seeds at pH 7.0. In the same experiment the percent germination of wild mustard seeds was also found to be significantly higher at pH 5.0 when compared to that in pH 7.0. It is, therefore, logical to plan future research to study if CO lowered the pH of the medium by the formation of H_2CO_3 and if the germination process in seeds was improved by the lowered pH in an atmosphere of saturated humidity.

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