Effects of Carbon Monoxide and Nitrogen Dioxide on Garden Pea and String Bean

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INTRODUCTION

The atmosphere is composed of a mixture of many gaseous substances that are present because of their natural occurences. Some of these gaseous substances are rather toxic to the biosphere if the amount present is more than the permissible level. It has been suggested that CO and NO_2 may cause as much as 22% decrease in crop yield (SPIERINGS, 1972). Our environment is being increasingly burdened by these pollutants and they are major constituents of photochemical smog (WAGNER, 1971). Referring to the atmosphere when it is clean, in the dry air near sea level the concentration of CO and NO_2 are 0.1 and 0.25 ppm respectively (AMERICAN CHEMICAL SOCIETY, 1969). This research takes into consideration levels of these pollutants that are attainable presently in many parts of the United States and other parts of the world (COUDRAY, 1970). This investigation therefore will give us some notion about the reactions of vegetable crops to increased amount of pollutants. Behavior in germination and growth of pea and bean plant species as affected by a toxic concentration of the pollutants were studied.

MATERIALS AND METHODS

Garden pea (Pisum sativum) and string bean (Phaseolus vulgaris) were exposed to 24 ppm of carbon monoxide and nitrogen dioxide. Pea and bean seedlings were germinated on vermiculite under ordinary laboratory conditions and were transplanted in four inch pots containing potting soil. A group of twenty pots of each species were then transferred to each cubical polyethylene chamber of uniform size (3'x 3'x 5'). All the seedlings used in the experiment were two weeks old. These chambers experienced about the same temperature (24-26^{o}C) and light conditions of the laboratory. Incandescent light bulbs of the laboratory were turned on for about twelve hours a day during day-time. The first chamber experienced the laboratory atmosphere. The second one maintained 24 ppm of CO and the last one maintained 24 ppm of NO_2 in addition to laboratory atmosphere confined in the chamber. The pollutant gases were prepared chemically in the laboratory. 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. Observations as an increase in stem length and leaf number were recorded every 72 hours. The investigation was started out with twenty seedlings per treatment. However, due to periodic death data were collected from the replicates that survived. The tables and figures in this report represent only the mean values as demonstrated by the surviving replicates. After the first experimentation was over pea and bean seeds, fifty of each species in duplicates, were allowed to germinate on vermiculite under the same conditions of the experimental chambers as described above and the germination percent was recorded. Tables and figures in this report represent only the mean values of percent germination.

RESULTS

Germination was delayed about 48 hours in bean seeds being exposed to 24 ppm nitrogen dioxide as compared to control. The total germinability of bean seeds was also affected when treated with nitrogen dioxide. Otherwise no apparent difference was noted in the precess of germination among treated seeds and the control in experimental seeds species. Observations on germination have been recorded in Table 1 and are plotted in figures 1 and 2. On studying the rate of death among treated pea seedlings it was observed that the death rate was not enchanced among treated seedlings as compared to the control (Figure 3) However, treated bean seedlings started dying from the sixth day since the exposure to the pollutants (Table 2). Bean seedlings treated with nitrogen dioxide were affected more as compared with the treatment with carbon monoxide (Figure 4). On the 12th day since the exposure to the pollutants, 65% of the bean seedlings treated with carbon monoxide survived while only 20% survived being treated with nitrogen dioxide. On the 18th day since the exposure to pollutes none of the bean seedlings survived being treated with nitrogen dioxide while about 30% of them survived being treated with carbon monoxide.

There was no apparent difference among control and treated seedlings when increase in stem length was taken into consideration (Table 3). This observation was true for both of pea and bean seedling (Figure 5,6).

Effects of pollutants on the formation of new leaves and dropping of old leaves were studied (Figure 7,8). Carbon monoxide decreased the formation of new leaves, and increased dropping of old leaves in pea seedlings when compared with the control (Table 4). Formation of new leaves was totally checked in the treated bean seedlings by the eighteenth day since the expsoure to pollutes (Table 5). Leaf-drop reached its maximum level on the 15th day since the exposure to carbon monoxide in bean seedlings.

TABLE 1

Germination Percent of Experimental Seeds

DAYS	CONTROL		CO		NO_2	
	Pea	Bean	Pea	Bean	Pea	Bean
1	0		0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	17	37	23	40	15	0
5	29	50	43	53	15	5
6	55	59	58	67	35	46
7	79	62	74	74	63	68
8	85	65	83	84	70	68
9	93	67	96	89	74	76
10	95	70	97	91	86	78
11	98	74	97	94	94	79
12	98	89	98	96	96	79

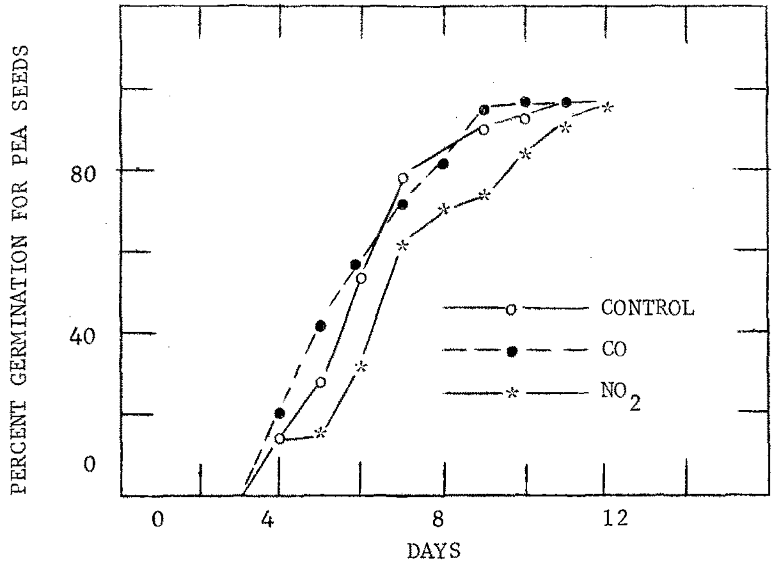

Fig. 1. Germination percent of pea seeds

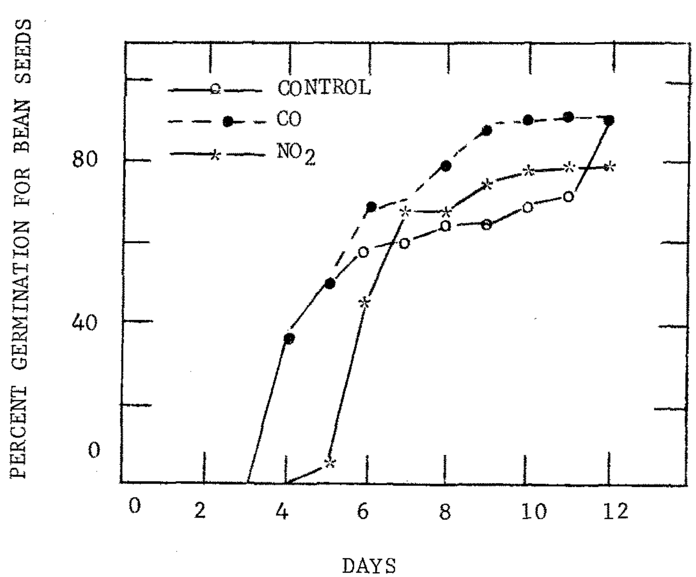

Fig. 2. Germination percent of bean seeds

TABLE 2

Survival Percent of Experimental Seedlings

DAYS	CONTROL		CO		NO_2	
	Pea	Bean	Pea	Bean	Pea	Bean
0	100	100	100	100	100	100
3	100	100	100	100	100	100
6	7	100	95	100	100	100
9	00	100	55	90	60	80
12	00	90	00	65	00	20
15		70		65		10
18		30		30		0
21		0		5		0

TABLE 3

Increase In Stem Length of Experimental Seedlings

DAYS	CONTROL		CO		NO_2	
	Pea	Bean	Pea	Bean	Pea	Bean
3	5.6	4.4	5.6	3.2	6.0	3.0
6	1.1	0.7	1.1	0.8	1.2	1.0
9	0.6	0.8	0.0	2.4	2.8	0.6
12	0.0	1.0	0.0	2.7	0.0	1.0
15		1.6		1.5		0.0
18		0.0		1.1		0.0

TABLE 4

Increase and Decrease in Number of Pea Leaves

DAYS	CONTROL		CO		NO_2	
	Increase	Decrease	Increase	Decrease	Increase	Decrea
3	1.9	0.0	3.1	0.0	1.8	0.0
6	0.6	0.3	1.2	1.1	1.8	1.2
9	0.0	0.71	0.2	0.05	0.0	1.8
12	0.0	0.0	0.0	1.5	0.0	0.0

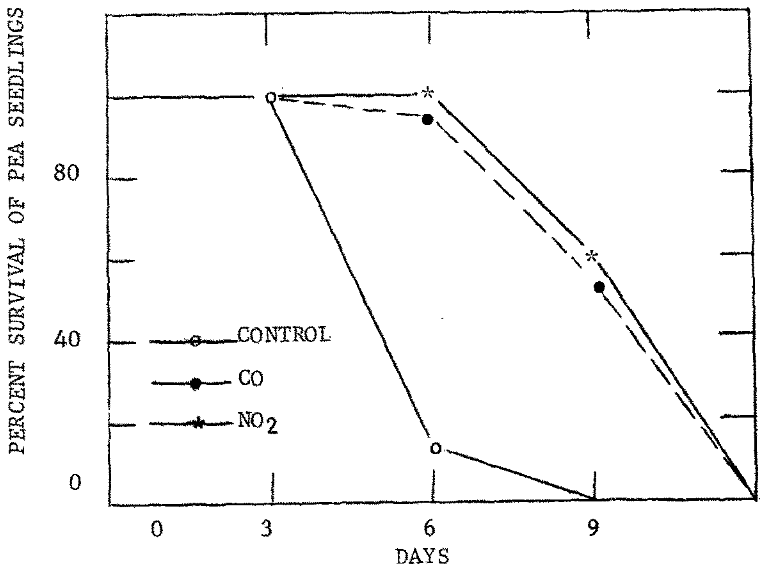

Fig. 3. Survival percent of pea seedlings

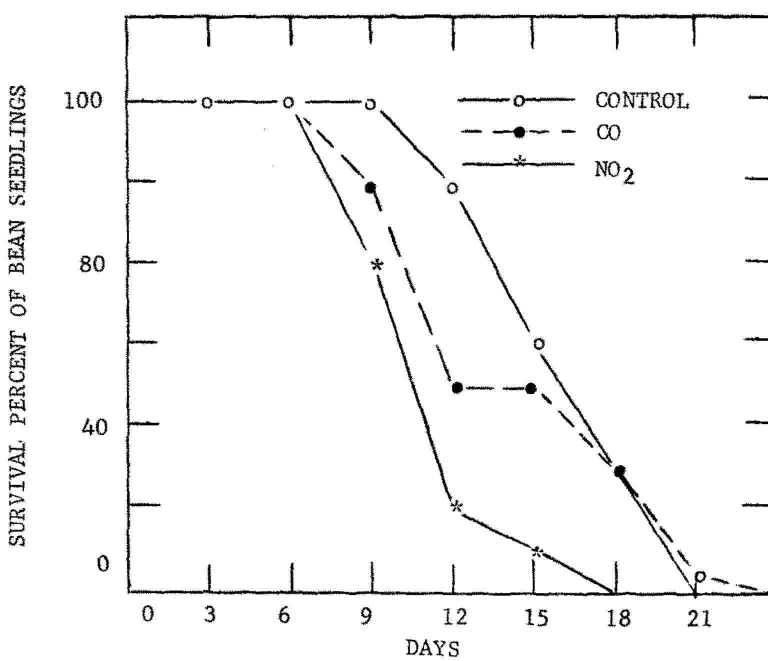

Fig. 4. Survival percent of bean seedlings

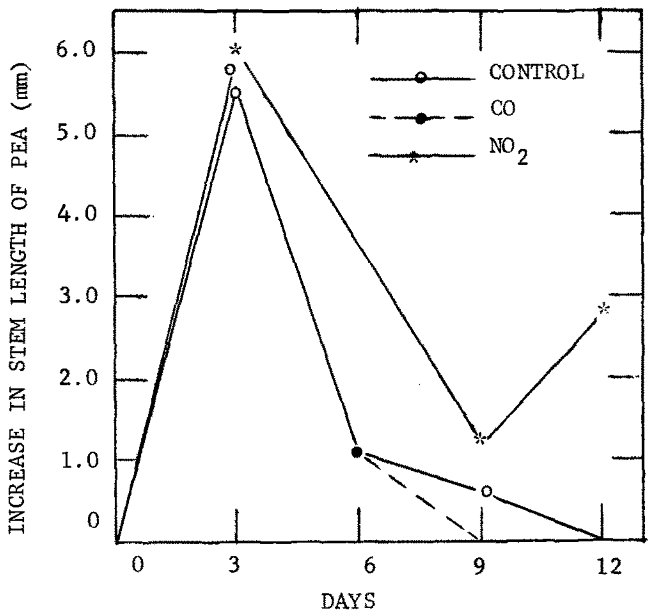

Fig. 5. Increase in length of stem in pea seedlings

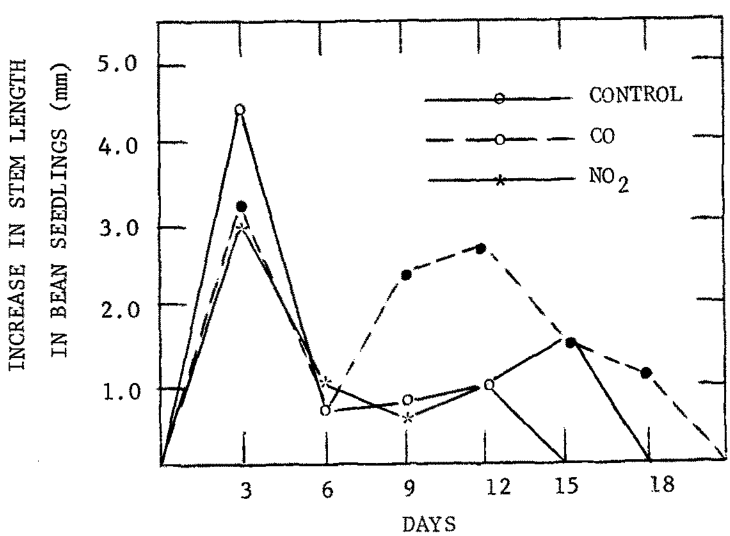

Fig. 6. Increase in length of stem in bean seedlings

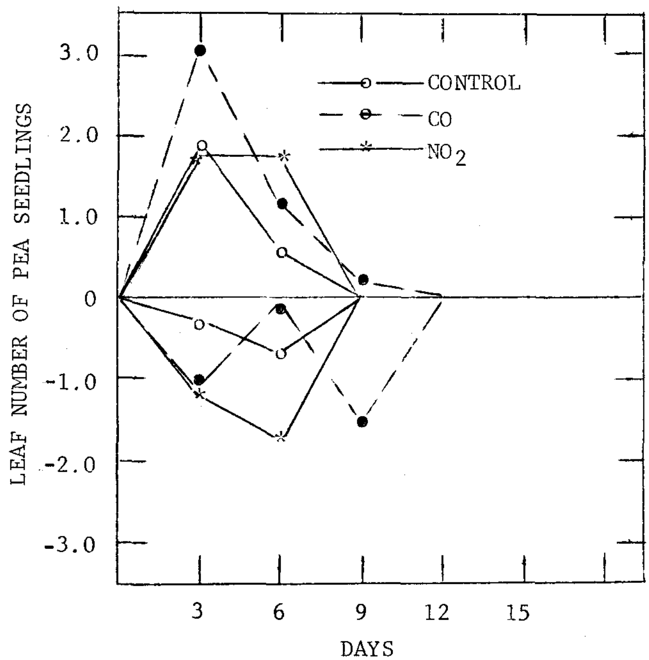

Fig. 7. Increase and decrease in leaf number of pea seedlings

TABLE 5

Increase and Decrease in Number of Bean Leaves

CONTROL		CO		NO_2	
Increase	Decrease	Increase	Decrease	Increase	Decrease
2.05	0.10	1.85	0.45	1.90	0.10
0.75	0.40	1.05	0.55	0.70	1.13
0.25	0.05	0.55	0.15	0.71	0.25
0.77	0.07	0.04	0.38	1.00	2.5
1.07	0.33	1.38	0.00	0.00	0.0
3.33		0.00		0.00	

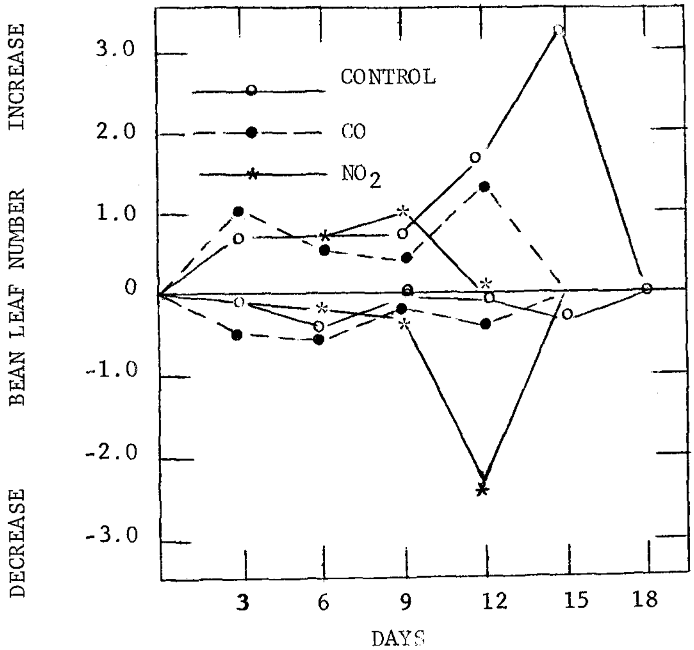

Fig. 8. Increase and decrease in leaf number of bean seedlings

DISCUSSION

From the data presented here it is quite evident that high levels of carbon monoxide and nitrogen dioxide affected seeds and seedlings of garden pea and string bean to different degrees. Treatment with nitrogen dioxide caused delay in germination in bean seeds probably making oxygen less available to bean seeds necessary for germination. Treatment with nitrogen dioxide caused higher death rate in bean plants in comparison to the treatment with carbon monoxide. This is probably due to higher sensitivity of bean species to nitrogen dioxide. This probably also explains why pea seedlings were less affected by the given amount of pollutes in comparison to bean seedlings. The length of the stem was not noticably affected in pea and bean seedlings by the treatment with the pollutes. Probably only epidermal cells of stems were affected.

Pollutes retarded formation new leaves and increased dropping of old leaves in pea and bean seedlings. It was reported that an exposure of 1 ppm of NO_2 caused severe defoliation in navel oranges (THOMPSON, 1970)

An application of 0.4-0.5 ppm of NO_2 for 21 to 45 days resulted in the development of smaller leaves and shorter leaf petioles (SPIERINGS, 1972). This probably because NO_2 is not only a poisonous gas but it is also a frequent constituent of photochemical smog (LORAINE, 1972). NO_2 has been known to inhibit apparent photosynthesis of oats and alfalfa at concentrations below those required to cause visible injury or damage. There appeared to be a threshold concentration of about 0.6 ppm for nitrogen dioxide. An additive effect in depressing apparent photosynthesis is occured when the plants were exposed to a mixture of NO and NO_2 (HILL ET AL 1970). It is well known that carbon monoxide has special affinity for tetrapyrrol hemoglobin in animal system (WAGNER, 1971). It is probable that CO might have affinity for tetrapyrrol cytochromes and chlorophyll affecting both respiration and photosynthesis in plants. This probably explains why pea and bean seedlings were affected to some extent by the given amount of carbon monoxide.

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