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Plant Ecology

MORPHOLOGICAL RESPONSES OF WHEAT PLANTS TO NITROGEN DIOXIDE EXPOSURES

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Fumigation of wheat plants with 1 ppm of nitrogen dioxide (NO_2) was carried out in closed polythene chambers for two hours daily between the 20th and 100th day of their growth. The treatment initially stimulated the growth of plants but at later stages there was an obvious growth suppression when the cumulative NO_2 dose exceeded 40 ppm. The protein content in grains from NO_2 fumigated plants was relatively higher than those of the control plants.

INTRODUCTION

Oxides of nitrogen are major air pollutants in urbanized and industrialized areas. The importance of NO_2 lies in its direct effect on plants and animals and its role in the photochemical smog cycle (Anon, 1962). Nitrogen dioxide levels of 118 to 156 $\mu g/m^3$ over 6 months have been implicated in producing adverse effects on human health. Detection of phytotoxic nature of NO_2 has been based upon obvious symptoms on the leaf lamina, colour changes of the leaves and reduction in growth and production (Jacobson & Hill, 1970). MacLean *et al.* (1968) demonstrated nonspecific marginal and intercostal necrosis in 14 ornamental species and six citrus varieties. Pintobean plants were visibly damaged by exposure to 3 ppm of NO_2 for 4 to 8 hr (Middleton *et al.*, 1958). Growth suppression and foliar distortion of tomato and pintobean plants exposed to less than 1 ppm of NO_2 for 10 to 22 days were observed by Taylor and Eaton (1966).

In the present work, the chronic effects of increasing cumulative doses of NO_2 on wheat plants have been studied in closed polythene greenhouse chambers. The experiments were conducted from November 1976 to April 1977.

MATERIAL AND METHODS

Plants of spring wheat (*Triticum aestivum* var. RR21) were grown in plots measuring 1 m^2 under natural field conditions in the Botanical Garden of the Banaras Hindu University. The plants were fumigated with 1 ppm of NO_2 when they were 20 days old.

Fumigation and sampling procedure

The pollutant NO_2 gas was produced by the action of dilute nitric acid on 0.1% aqueous sodium nitrite solution (Soni, 1975). Concentration of 1 ppm of gas in

m^3 chamber was obtained by reacting 1.5 ml of sodium nitrite solution with dilute HNO_3. Wheat plants were subjected to NO_2 fumigation for 2 hr daily in m^3 polythene (0.025 mm thick) chambers supported by cubical iron frame. The base of the chamber was embedded in the soil to avoid any possible leakage during gassing. The fumigation schedule and the cumulative pollutant doses are given in Table I. The control plants were also enclosed in polythene chambers without the gas.

TABLE I

Fumigation and sampling schedule of wheat plants (Fumigation continued daily for 2 hr after the plants attained the age of 20 days)

Plant Age (days)	Concentration (ppm)	Cumulative dose (conc. × hr × days) (ppm)	Sampling order
1-20	—	—	—
21-40	1	1×2×20=40	1
41-60	1	1×2×40=80	2
61-80	1	1×2×60=120	3
81-100	1	1×2×80=160	4
101-120	1	1×2×80=160	5
121-135	—	—	6 (Harvesting)

Plant analyses

Sampling of plants was done according to the schedule given in Table I. Plants with a single block of soil in the form of monoliths were dug out carefully keeping their root and shoot systems intact. These monoliths were thoroughly washed to remove the soil particles. Then the lengths of root and shoot, number and area of photosynthetic leaves, number of tillers, number and length of ears formed were measured. The weight of oven-dried plant material was taken for biomass calculation. The average value of five replicates was taken for each parameter. The average number of grains per spike and weight of 1,000 grains of control and treated plants were obtained from those harvested at the age of 135 days. The data were analysed statistically for S.D.

Percentage nitrogen

The total nitrogen content in the plant samples was determined by the micro-Kjeldahl technique as outlined by Misra (1968) and the values were expressed as percentage of dry weight. The percentage of nitrogen was multiplied by a constant factor of 5.7 to get the per cent protein content (Horwitz, 1970).

RESULTS AND DISCUSSION

The data in Table II represent the chronic effects of NO_2 on the morphological features of wheat plants. It is obvious from the table that at the initial stages of growth when the cumulative pollutant dose was low, the plants showed better growth performance. It appears that NO_2 serves as a nitrogenous fertiliser at mils

TABLE II

Morphological characteristics of control (C) and fumigated (F) wheat plants at different growth stages

Parameters	Treatment	Plant age (days)				
		40	60	80	100	120
Average shoot length (cm)	C	44.1±0.17	68.2±0.13	107.8±1.26	114.3±1.72	115.2±1.63
	F	44.8±0.15	67.6±0.19	104.1±1.35	108.6±1.89	109.3±1.83
Av. root length (cm)	C	9.2±0.09	11.4±0.05	13.5±0.16	15.2±0.26	15.3±0.16
	F	9.6±0.11	11.5±0.03	13.1±0.12	14.6±0.21	14.8±0.15
Biomass (g/plant)	C	12.8±0.14	23.6±0.34	43.3±1.73	52.5±1.12	55.6±1.42
	F	13.6±0.12	22.2±0.29	39.8±1.54	48.2±1.19	51.0±1.64
Tillers/plant	C	6.0±0.00	10.0±0.00	17.0±0.00	17.1±0.00	17.0±0.00
	F	6.0±0.00	9.0±0.00	15.0±0.00	15.0±0.00	15.0±0.00
Av. no. of leaves/plant	C	16.0±0.21	24.5±0.41	32.1±0.86	37.4±0.85	26.2±1.38
	F	16.5±0.18	23.2±0.38	29.7±0.93	35.2±0.62	22.8±1.46
Leaf area/plant (cm^2)	C	225.2±1.61	310.7±3.57	744.3±4.96	914.6±7.63	708.3±4.87
	F	230.3±1.83	329.4±4.29	702.8±6.71	852.0±9.23	685.2±5.14
No. of ears/plant	C	—	—	16.0±0.00	17.0±0.00	17.0±0.00
	F	—	—	15.0±0.00	15.0±0.00	15.0±0.00
Av. length of ear (cm)	C	—	—	16.8±0.10	17.9±0.24	18.2±0.25
	F	—	—	16.3±0.13	16.8±0.27	17.1±0.28

doses (Faller, 1972). Bennett *et al.* (1974) also concluded that certain air pollutants could stimulate plant growth. This becomes apparent by looking at the data on average lengths of shoot and root of 40 days old control and fumigated plants; the respective values being 44.1 and 9.2 cm in the former and 44.8 and 9.6 cm in the latter. Similarly the biomass values of control and fumigated plants of identical ages were 12.8 and 13.6 g/plant, respectively. However, at later stages of growth, the biomass values decreased as the pollutant dose increased. This is evident from the values of 55.6 and 51.0 g/plant of 120 days old control and fumigated plants, respectively, at the cumulative ($c \times t$) dose of 160 ppm. These results are in agreement with those of Thompson *et al.* (1970) who observed decrease in yield of navel orange on exposure to NO_2 as well as those of Hill and Bennett (1970) who demonstrated inhibition of photosynthesis and consequent reduction in biomass of oat and alfalfa plants under the influence of NO_2.

It was observed that at the age of 40 days, the colour of the fumigated leaves was more green than that of the control leaves. This was possibly due to a higher chlorophyll content in the NO_2-exposed leaves. However, the leaves between the ages of 60–80 days developed bifacial yellow-brown necrotic patches in their middle portion after they had received a cumulative NO_2 dose of 120 ppm. This type of leaf response could be due to either acidification or photo-oxidation of the leaf pigments (Zeevaart, 1976).

The length and number of spikes/plant, the average number of grains/spike and the weight of 1,000 grains, were lower in treated plants, indicating that there was metabolic impairment of flowering. The protein content of the grains of fumigated plants was improved by 2.4% (Table III). From the increase in the percentage of nitrogen and protein content, one would assume anabolic utilisation of NO_2 in the plant body (Zeevaart, 1976).

TABLE III

Grain characteristics of control and fumigated wheat plants

Characteristics	Control	Fumigated
Av. no. of grains/spike	47±1.21	42±1.26
Wt. of 1000 grains (g)	35.7±1.33	32.9±1.14
Moisture content (%)	11.1±0.07	10.7±0.05
Nitrogen content (%)	2.51±0.13	2.93±0.09
Protein content (%)	14.3±0.13	16.7±0.09

Thus it may be concluded that fumigation with 1 ppm of NO_2 daily for 2 hr for 80 days, leads to growth suppression and foliar damage of wheat plants. However, it is likely that at the initial stages of fumigation, NO_2 may be assimilated by the tissues.

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