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Influence of Peroxyacetyl Nitrate (PAN) on Water Stress in Bean Plants[1]

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Abstract. Bean plants (*Phaseolus vulgaris* L. cvs. Provider and Stringless Black Valentine) were exposed to 395 μg/m³ (0.08 ppm) peroxyacetyl nitrate (PAN) for 0.5 hr and subjected to drought stress following exposure. PAN influenced the plant water potential of PAN-sensitive 'Provider' resulting in visible wilting and reduced soil moisture content. There was no effect of PAN on the water relations of the PAN-tolerant 'Stringless Black Valentine'.

Macroscopic foliar injury is frequently used for assessing plant response to air pollutants. However, vegetation if often exposed to dosages of air pollutants which do not elicit visible foliar injury (sub-threshold dosages). One effect of sub-threshold levels of air pollutants may be an altered reaction to a subsequent physiological stress such as changes in plant water potential.

Few studies have dealt with the direct effects of sub-threshold dosages of photochemical oxidants on plant water potential. Cotton leaves exposed to sub-threshold levels of ozone took up 50% more sucrose than unexposed control leaves (9). Tomato plants exposed to a sub-threshold dosage of ozone plus vapors of 1-n-hexene exhibited a decreased water uptake and transpiration rate (2). In both studies, the effect of the air pollutant was postulated to be due to altered permeability of cell membranes. 'Provider' bean seedlings exposed to sub-threshold levels of PAN, 271 or 405 μg/m³ for 1.0 or 0.5 hr, respectively, exhibited stomatal conductance rates similar to unexposed control plants (3). The objective of this study was to determine if exposure to sub-threshold dosages of PAN altered the plant water potential of 2 bean cultivars differing in susceptibility to PAN.

'Provider' and 'Stringless Black Valentine' bean were utilized in this study because of their respective susceptibility and tolerance to PAN (5); 160 seeds of each cultivar were planted in vermiculite initially treated with 5.3 g/liter solution of 20N-19P-18K fertilizer. The vermiculite was then moistened with water as required until cotyledons emerged 5 days after planting. Two days later 48 uniform plants of each cultivar were transplanted into individual 590-cc plastic pots containing about 360 cc of aerated-steam treated peat:perlite:clay-loam soil (1:1:1, v/v/v). The potting mix was compacted uniformly and 200 ml of water were added to each pot. An additional 200 ml of water were added to each pot 2 days after transplanting. All plants were grown in a controlled environment chamber maintained at 24°C, 70% relative humidity and a 12-hr photoperiod with a light intensity of 25 klx, hereafter referred to as "standard conditions."

Three days after transplanting, 24 plants of each cultivar were exposed to 395 ± 74 μg/m³ (0.08 ± 0.015 ppm) PAN for 0.5 hr at standard conditions in a modified controlled environment chamber (11). Preliminary experiments revealed that this was a sub-threshold dosage of PAN for 'Provider'. At the time of exposure, the primary leaves were about 50% mature and the secondary leaves were just emerging. The pots were arranged randomly within the chamber. All plants received the same 3-hr minimum pre- and post-exposure light treatment considered necessary for symptom development (8). PAN was generated, collected, and stored as described by Stephens (7). During exposure, the PAN concentration was monitored at about 10 min intervals by taking air samples from the chamber with a syringe and injecting them into a calibrated (6) gas chromatograph with an electron capture detector (4).

Immediately following exposure to PAN, the plants were returned to the controlled environment chamber and maintained at standard conditions. Groups of 12 plants of each cultivar were treated as follows: exposed to PAN, water withheld following exposure (+PAN, $-H_2O$) or exposed to PAN, water supplied following exposure (+PAN, $-H_2O$). Control plants not exposed to PAN also had water withheld (–PAN, $-H_2O$) or water supplied (–PAN, $+H_2O$). Plants in the $+H_2O$ treatment received 200 ml of water every 2 days. Preliminary experiments revealed that with this regime, water potential measurements were less variable than when pots were maintained at or above container capacity (10). Water was withheld from $-H_2O$ treatments for the duration of the experiments.

Water potential and soil moisture measurements were determined on the day of exposure and on the 2nd and 4th days following exposure, at the same time of day. Four plants of each cultivar in each treatment were used to determine water potential and soil moisture on each day. Stems were cut 1 cm below the cotyledons and the water potential of the upper portion was determined using a pressure bomb (1). Pressure was applied to the bomb chamber with nitrogen until the xylem sap appeared at the cut stem surface projecting from the chamber. Measurements were recorded to the nearest 0.5 pound pressure per square inch and then converted to negative bars.

Following the water potential measurements, the lower stem and roots were removed form the soil and the percentage soil moisture was determined on a volume basis. Container capacity (10) was 48%. The volume percentage of water at the permanent wilting point was estimated to be 3%. Measurements of soil moisture were within the limits of available soil moisture. The study was repeated 4 times.

Symptoms. Neither 'Stringless Black Valentine' nor 'Provider' sustained macroscopic symptoms following exposure to 395 μg/m³ PAN for 0.5 hr. 'Provider' (PAN susceptible) and 'Stringless Black Valentine' (PAN tolerant) responded differently to water stress following exposure.

'Provider' (PAN-susceptible). On the first day, there were no significant effects of PAN on water stress. Plants in the +PAN, $-H_2O$ treatment had a significantly greater negative water potential on the 2nd and 4th days following exposure than did plants in the –PAN, $-H_2O$ treatment (Table 1). Plants exposed to PAN had a significantly lower percentage of soil moisture on the 2nd and 4th days than the plants not exposed to PAN (Table 2).

Visible wilting was caused by PAN exposure. Plants in the +PAN, $-H_2O$ treatment began to wilt on the second day following exposure whereas the plants in the –PAN, $-H_2O$ treatment did not begin to wilt until the 3rd day. On the 4th day equal numbers of plants in the +PAN, $-H_2O$ and –PAN, $-H_2O$ were wilted.

The increased water uptake and tran-

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Table 1. Influence of PAN and water on plant water potential of 'Provider' (PROV) and 'Stringless Black Valentine' (SBV) bean plants exposed to 395 $\mu g/m^3$ PAN for 0.5 hr; PROV is susceptible to PAN, whereas SBV is tolerant.

Treatment		Water potential (negative bars)[z]					
		Days after exposure 0		2		4	
PAN	H_2O	PROV	SBV	PROV	SBV	PROV	SBV
+	–	6.5a	6.2a	6.9a	6.0a	8.4a	8.6b
–	–	6.5a	6.1a	6.0b	6.3a	7.1b	9.1a
+	+	6.7a	6.0a	5.3c	5.0b	4.4c	4.4c
–	+	6.6a	5.9a	5.4c	5.2b	4.4c	4.6c

[z]Mean separation within columns by Duncan's Modified (Bayesian) Least Significant Test Value (k = 500), 1% level. Values represent the average of 16 plants.

spiration of relatively susceptible bean cultivars exposed to sub-threshold concentrations of PAN has several implications to laboratory studies and greenhouse plantings as well as field observations. The volume of soil in which laboratory and greenhouse plants are grown is generally much smaller than the available volume of soil in the field. Consequently, an increase in water uptake by plants exposed to PAN would deplete the available water at a faster rate than plants not exposed to PAN. Plants exposed to PAN would require more frequent watering than those unexposed to prevent wilting. If wilting should occur, the experimental use of these plants may be complicated by irreversible cellular damage.

In contrast to our findings, Metzler and Pell (3) did not observe a change in stomatal conductance (a measure of transpiration as well as gas exchange) of 'Provider' bean plants exposed to subthreshold dosages of PAN. However, stomatal conductance or transpiration is only one factor contributing to total plant water potential. PAN may affect internal leaf water relations without affecting transpiration and still change total plant water potential. Since we did not measure stomatal conductance, we cannot accurately assess its possible role in this study. The sand culture utilized by Metzler and Pell may have minimized the potential for PAN to induce water stress.

Stringless Black Valentine (PAN-tolerant). Plants in the +PAN, $-H_2O$ treatment had a significantly less negative water potential on the 4th day following exposure than the treatment –PAN, $-H_2O$. There were no statistically significantly differences between these treatments on the first 2 days (Table 1). There were neither significant differences in water potential between the treatments +PAN, $+H_2O$ and –PAN, $+H_2O$ (Table 1) nor in percentage of soil moisture between the plants exposed to PAN and those not exposed to PAN (Table 2) at any time after PAN exposure. PAN did not stimulate visible wilting in this cultivar. On the 2nd, 3rd, and 4th days following exposure, equal numbers of plants in the treatments +PAN, $-H_2O$ and –PAN, $-H_2O$ were wilted.

Both cultivars treated with either +PAN $+H_2O$ or –PAN, $+H_2O$ regime exhibited significantly less negative water potential 4 days after exposure as compared to the unwatered plants (Table 1). Since seedlings were exposed to PAN only 3 days after transplanting, the roots may not have been as well established in the soil as they were 4 days after exposure. This change in negative water potential was not seen in the +PAN, $-H_2O$ or –PAN, $-H_2O$ treatments, probably due to the masking effect of the drought stress.

Table 2. Percent soil moisture of potted 'Stringless Black Valentine' (SBV) and 'Provider' (PROV) bean plants exposed to 395 $\mu g/m^3$ PAN for 0.5 hr.

Cultivar	PAN treatment	Soil moisture (% by volume)[z] Days after exposure 0	2	4
PROV	+	43.3a	24.4b	19.9b
	–	43.4a	30.4a	22.2a
SBV	+	43.2a	27.6a	20.3a
	–	42.9a	26.6a	21.2a

[z]Mean separation within columns within cultivar variety by Duncan's Modified (Bayesian) Least Significant Test Value (k = 500), 1% level; plants were not watered following Day "0."

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Response of Pinto Bean Plants Exposed to O_3, SO_2, or Mixtures at Varying Temperatures[1]

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Abstract. **Pinto bean plants (*Phaseolus vulgaris* L. cv. Pinto 111) in the unifoliolate leaf stage were exposed for 3 hours to 0.8 ppm SO_2, 0.25 ppm O_3, or a mixture of the 2 pollutants at these concentrations at 15, 24, or 32°C. Foliage exposed to O_3 alone developed adaxial stipple and leaves exposed to SO_2 alone developed interveinal necrosis. The mixture of O_3 and SO_2 induced O_3-type symptoms at 32° and SO_2-type symptoms at 15°. Both symptom types were present at 24°. Some abaxial glazing or silvering was also induced by the mixture, and was most common at 15° and 24°. Ozone and SO_2 each induced greater foliar injury at 15° or 32°, as compared to 24°. The mixture of O_3 and SO_2 induced greatest macroscopic foliar injury at 15°. The degree of adaxial vs abaxial leaf surface injury varied with temperature.**

The influence of exposure temperature on the macroscopic symptom intensity and character of plants exposed to a mixture of air pollutants has not been report-

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