

Foliar injury responses of 24 bean cultivars (*Phaseolus vulgaris*) to various concentrations of ozone

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Abstract

In the summer of 1981, symptoms on leaves of field grown beans (*Phaseolus vulgaris*) were noticed suggesting O₃ injury. In order to determine their relative sensitivity primary leaves of 24 bean cultivars were exposed to various concentrations of O₃. Differences in foliar injury responses between cultivars were affected by O₃ concentration. The cultivars Pros/Gitana and Stratego were the most sensitive, whereas Berna and Narda were the most insensitive. The symptoms observed in practice may be attributed to O₃. Sensitivity of Stratego primary leaves clearly depended on plant age. This cultivar will be tested as an indicator plant for O₃.

Additional keywords : air pollution.

Introduction

A number of cultivars of bean (*Phaseolus vulgaris* L.) are known to be very sensitive to ozone (O₃). Some sensitive cultivars have even been used in biomonitoring programs in some countries (e.g. Manning and Feder, 1980). In the Netherlands the sensitive tobacco cultivar Bel W₃ is used to monitor O₃ effects for ten years now (Floor and Posthumus, 1977).

In the summer of 1981 injury on leaves of some cultivars of field grown beans was noticed after episodes with elevated concentrations of O₃. Injury consisted of dark brown lesions, especially on the oldest leaves. These symptoms may be attributed to O₃ but in the Netherlands they have been attributed to sunscald as others had done previously (Weaver and Jackson, 1968).

In an attempt to determine whether the injury could be due to O₃, a study was undertaken to determine the O₃ sensitivity of a number of bean cultivars which are grown in the Netherlands. Because of the known sensitivity of the Canadian cultivar Seafarer (Beckerson et al., 1979) its foliar injury response was also evaluated. Subsequently, the period of maximal sensitivity of one of the most sensitive cultivars was determined in order to evaluate its usefulness as an indicator plant for O₃.

Materials and methods

Seeds of 24 bean cultivars (*Phaseolus vulgaris*) were planted in 12 cm plastic pots,
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in a high fertility peat-clay potting mixture (Triomf no 17, modified, Trio BV, Westerhaar) and grown in a greenhouse with charcoal filtered air at 22 ± 3 °C and $72 \pm 6\%$ relative air humidity. Plants received additional light from incandescent bulbs (HPL 400 W) during 12 h a day. Pots were watered daily with tap water. Fourteen days after planting beans were thinned to two plants per pot and exposed to O₃.

Experiments were conducted in 8 m³ walk-in fumigation chambers in a greenhouse from 9.00 until 12.00 h early October 1981. Temperature was 21 ± 2 °C and relative air humidity $70 \pm 6\%$, while plants received additional light from fluorescent tubes resulting in a minimum light intensity of circa 35 Wm⁻². Incoming air was filtered by activated charcoal with a flow rate of 4 m³ min⁻¹ for each of three chambers. Different concentrations of O₃ were produced by silent electrical discharge in pure oxygen and added to the air stream of two chambers. Plants in the third chamber served as a control. Concentrations of O₃ were monitored with a Dasibi 1003 AH analyzer. For each O₃ concentration (160, 200, 260 and 320 µg m⁻³) treatments were conducted twice with four plants per treatment for each cultivar.

Two days after the treatments visible injury on primary leaves was assessed using a modified Horsfall-Barratt scale (Hofstra and Ormrod, 1977) ranging from 0 (no injury) to 12 (100% injury). Mean injury ratings for each cultivar were calculated for each treatment. A split-plot analysis of variance on two replicates with concentrations on the main plots and cultivars on the split plots was used to test the cultivar responses. Where the F-test showed significant differences between responses, ratings for each concentration were compared pairwise in a LSD-test.

To study the influence of plant age on the sensitivity of primary leaves to O₃, seeds of the sensitive bean cultivar Stratego were planted at various time intervals and cultivated as described above. On November 30th four treatments of 3 h each with 260 µg O₃ m⁻³ were given to a total of sixteen plants for each of twelve plant ages, ranging from 11 to 36 days after sowing. Two days after the treatments visible injury to primary leaves and to the first trifoliate leaf was assessed.

Results

Immediately after the exposures with high concentrations of O₃ sensitive cultivars showed a grey/green flecking between the veins, which ultimately developed in white/tan bifacial necrosis. All cultivars exhibited coloured, mostly dark brown lesions (1-2 mm), while some leaves also became chlorotic. In general symptoms fully developed in two days.

Results of the analysis of variance showed significant O₃ concentration and cultivar effects ($P < 0.01$) but also a significant concentration \times cultivar interaction ($P < 0.01$). So differences in foliar injury responses between cultivars were dependent on O₃ concentration.

Calculated injury indices for each concentration illustrate the different responses of the 24 bean cultivars (Table 1). Pros/Gitana and Stratego were the most sensitive cultivars, whereas Berna and Narda were the most tolerant ones. Several bean cultivars grown in the Netherlands were more sensitive than cultivar Seafarer. Injury on all cultivars generally increased with an increase in O₃ concentration. In accordance with the significant concentration \times cultivar interaction results indicated that low concentrations were needed for detection of the most sensitive cultivars and high

Table 1. Injury indices on primary leaves of 24 bean cultivars (*Phaseolus vulgaris*) exposed to various concentrations of O₃ for 3 h.

Cultivar	O ₃ concentration (μg m ⁻³)			
	160	200	260	320
Pros/Gitana	4.2 ab ¹	8.0 a	9.0 a	11.1 a
Stratego	5.3 a	7.6 ab	8.4 ab	10.9 ab
Prelubel	2.9 bc	8.0 a	5.4 def	10.5 ab
Tuf	1.1 cd	5.8 abcde	8.2 abc	11.2 a
Prelude	1.6 cd	6.7 abc	6.9 abcde	10.7 ab
Impala	1.0 cd	6.1 abcd	6.7 bcde	11.7 a
Lotus	1.6 cd	6.5 abcd	6.0 cdef	10.7 ab
Centrum	0.2 d	6.2 abcd	5.4 def	11.9 a
Flairco	2.8 bc	3.6 efgh	6.2 bcdef	9.9 abc
Bertires	1.5 cd	3.5 fgh	7.3 abcd	10.0 abc
Comprise	1.3 cd	5.6 bcdef	4.2 fgh	10.7 ab
Fran/Toccata	2.1 bcd	2.6 ghi	5.8 def	8.7 bcd
Seafarer ²	0 d	4.8 cdefg	4.0 fgh	10.3 ab
Lit	0 d	2.2 hij	5.6 def	10.3 ab
Hazet	0.9 cd	4.4 defg	4.7 efg	8.0 cde
Prevato	0 d	5.1 cdef	2.4 hij	10.4 ab
Colana	1.8 cd	2.7 gh	3.0 ghi	7.7 def
Precores	0 d	5.4 cdef	0.9 ijk	4.2 gh
Belami	0.2 d	0.3 j	2.0 hijk	7.4 def
Gamin	0 d	0.2 j	2.0 hijk	6.4 efg
Gro/Amicron	0.2 d	0.4 ij	0.3 jk	5.7 fgh
Grofy	0 d	0.1 j	0 k	3.5 hi
Narda ²	0.1 d	0.2 j	0.2 jk	1.5 i
Berna ²	0 d	0 j	0 k	1.6 i

¹ For each concentration injury indices followed by the same letters are not significantly different at the 5% level (LSD).

² Dry beans, all other cultivars are snap beans.

Tabel 1. Mate van beschadiging op primaire bladeren van 24 bonecultivars (Phaseolus vulgaris), die gedurende drie uur werden blootgesteld aan verschillende concentraties O₃.

concentrations for detection of the most tolerant ones. The cultivars Iprin, Rofin and Utopia were only exposed to 160 μg O₃ m⁻³ with mean injury indices of 0.2, 1.9 and 1.2, respectively.

As shown in Fig. 1 sensitivity of Stratego primary leaves to O₃ reached a maximum at 20 to 22 days after sowing. Primary leaves of both older and younger plants were much less sensitive. Furthermore, the decrease in injury response of the primary leaves was not compensated for by an increase in injury response of the first trifoliate leaf.

Fig. 1. Injury response of primary leaves (●) and first trifoliolate leaf (▲) of cv. Stratego to $260 \mu\text{g O}_3 \text{ m}^{-3}$ for 3 h in relation to plant age.

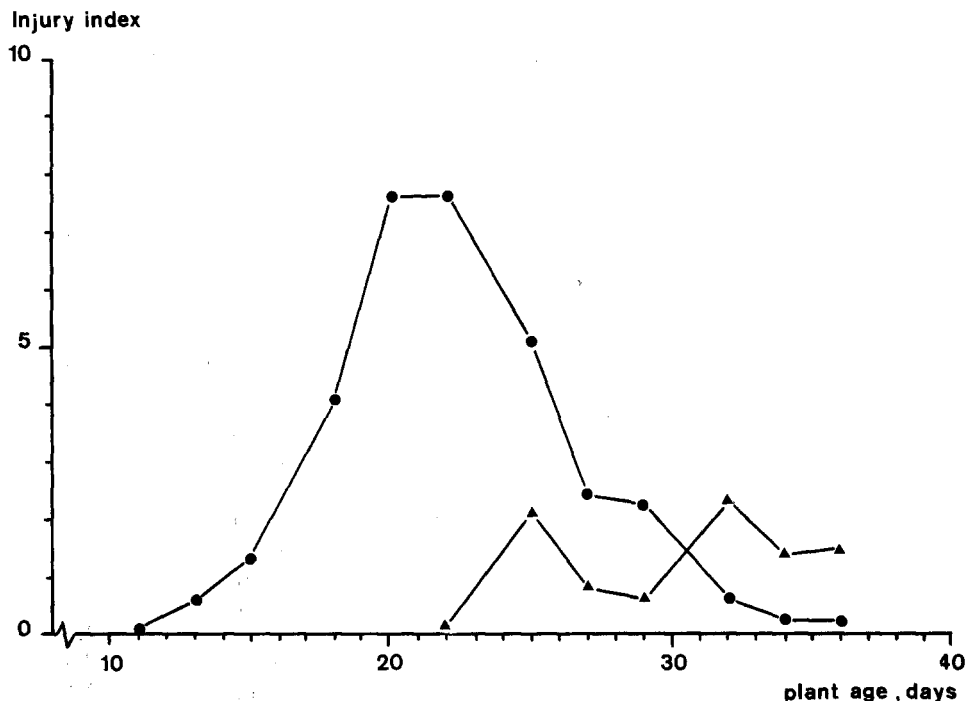


Fig. 1. Bladbeschadiging op primaire bladeren (●) en het eerste drietallige blad (▲) van cv. Stratego na begassing van 3 uur met $260 \mu\text{g O}_3 \text{ m}^{-3}$ in relatie tot de leeftijd der planten.

Discussion

The results of our experiments confirm previous observations, that bean cultivars are not equally sensitive to O_3 (Hucl and Beversdorf, 1982). Because none of the cultivars was completely resistant, foliar injury response to O_3 is of a quantitative nature. Furthermore a significant concentration \times cultivar interaction was found. Therefore, various concentrations of air pollutants must be used in screening programs. Differences in concentrations of the component under study may be one reason for the weak correlations between results of laboratory and field tests as found by Meiners and Heggstad (1979) and Beckerson et al. (1979). Different growth conditions (Lewis and Brennan, 1977) and presence of other air pollution components like SO_2 (Hofstra and Ormrod, 1977; Jacobson and Colavito, 1976) may be important as well.

The cultivars Berna and Narda appeared to be very tolerant to O_3 as was also found by Beckerson et al. (1979), whereas several cultivars were more sensitive than Seafarer. Because problems of severe injury in the field, as reported in Canada, have not been encountered, ambient concentrations of O_3 in the Netherlands are probably not of the same magnitude. Nevertheless, measurements showed that in the summer

of 1981 these concentrations equaled or exceeded those causing visible injury in our experiments. Considering level of ambient concentrations and nature of symptoms the observed injury to beans in practice may be attributed to O₃.

It was decided to start research in order to test bean cultivars as indicator plants for O₃. Similar approaches with an O₃-sensitive cultivar of pinto bean appeared to be successful (Oshima, 1974). Dugger et al. (1962) discovered that sensitivity of pinto bean primary leaves to O₃ was dependent on plant age. Our results showed that Stratego primary leaves were extremely sensitive 3 weeks after planting. In the screening tests, however, equal foliar injury responses were already found after 2 weeks. Seasonal changes in weather conditions were most probably responsible by influencing plant development in the greenhouse-grown plants.

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Samenvatting

Invloed van verschillende concentraties ozon op bladbeschadiging bij 24 bonecultivars (phaseolus vulgaris)

In de zomer van 1981 werden in het veld symptomen op bladeren van boon geconstateerd, die mogelijk een gevolg waren van te veel O₃ in de lucht. Ten einde de relatieve gevoeligheid te bepalen werden primaire bladeren van 24 bonecultivars blootgesteld aan verschillende concentraties O₃. Verschillen in het niveau van bladbeschadiging tussen de cultivars werden beïnvloed door de O₃-concentratie. De cultivars Pros/Gitana en Stratego waren het meest gevoelig, Berna en Narda daarentegen het meest ongevoelig. De in de praktijk op boon waargenomen symptomen kunnen aan O₃ worden toegeschreven. De gevoeligheid van de primaire bladeren van cultivar Stratego bleek afhankelijk te zijn van de leeftijd van de planten. Deze cultivar zal onderzocht worden op de bruikbaarheid als indicatorplant voor O₃.

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