The Influence of Ethylene on the Development of 5°C-Precooled ‘Apeldoorn’ Tulips during Forcing

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Abstract. When tulip bulbs infected with Fusarium oxysporum f. tulipae are present in the soil, ethylene concns up to 10 ppm can be measured in the soil atm. The greater the distance from the diseased bulbs, the lower the local concn of ethylene detected. The amounts of ethylene present in the soil can account for the observed growth inhibition of the shoots and roots and the blasting of the flower buds.

In the forcing of tulips it is often observed that the development of healthy bulbs is unfavorably influenced by the presence of bulbs infected with Fusarium oxysporum Schlechtt. f. tulipae Apte. This may result in inhibited growth of the plants and blasting of the flower buds. These disorders are sometimes attributed to an infection of the healthy bulbs with Fusarium from the infected bulbs. Schenk and Bergman (12) showed that infections can occur during forcing of 5°C-precooled bulbs. In a number of cases in which growth inhibition was observed, no symptoms of infection could be found. It is known that Fusarium-infected bulbs can produce relatively large amounts of ethylene (8) and that growth inhibition can be caused by ethylene (2, 5, 6, 9).

The present study was made to determine whether the presence of Fusarium-infected tulip bulbs during forcing could lead to concns of ethylene in the soil high enough to cause growth inhibition.

Bulbs (10/11 cm) of the cultivar ‘Apeldoorn’ lifted in summer 1969 and which had received a precooling treatment of 5°C during 15 weeks (7) were planted on March 3 at a depth of 6 to 7 cm in a box (12x12x10 cm) filled with dune sand and forced at 18°C. Two shrivelled and desiccated Fusarium-infected bulbs were planted in the box between healthy bulbs at the same depth (Fig. 1) and 9 copper tubes (12 cm long; 1 cm diam) were inserted vertically in the soil about 11 cm apart. The lower part of these tubes (7 cm) was perforated and the top was closed with a serum cap. At 3, 9, 17, and 34 days after planting, air samples from these tubes were analysed for the presence of ethylene by gas chromatography (Aerograph, model 1522-B, 5 ft column, 1/8 inch diam, porapak Q 80-100 mesh, flame ionisation detection, carrier gas N2).

The data from the gas analyses (Fig. 1) show that ethylene was produced and released by Fusarium-infected bulbs. The highest ethylene concns were found at points 3 and 7, corresponding to the locations of the diseased bulbs. The values obtained at 4 different times at point 3 were 6.0, 7.1, 4.5, and 1.5 ppm, and at point 7: 10.6, 6.6, 1.5, and 0.3 ppm. The lowest concns were measured at points 1 (0.6 to 0.3 ppm), 5 (1.3 to 0.2 ppm), and 9 (1.5 to 0.3 ppm). It is clear that the amounts of ethylene in the air samples decreased with increasing distance between the sampling place and the diseased bulbs. Increasing concns of ethylene found on the later sampling dates suggest that the ethylene producing system is exhausted after a period of about a month, when the Fusarium-infected bulbs are totally wasted. A correlation exists between the length of the plants and the distance to the diseased bulbs (Fig. 1). Almost 100% inhibition of extension growth occurred in the plants nearest to the infected bulbs (points 3 and 7). Plant growth at points 1, 5, and 9, the furthest from the infected bulbs, was inhibited only slightly or not at all when compared with control bulbs.

We also observed inhibition of the elongation growth of the roots (Fig. 2). Within a distance of 25 to 35 cm from points 3 and 7, all flower buds became blasted. The decrease of the ethylene concns and the decreasing retardation of extension growth with increasing distances from the infected bulbs suggests a causal relationship between growth inhibition of the shoot and roots and the presence of ethylene in the soil atm. Experiments were performed therefore in which 6 ppm ethylene was passed through the soil or introduced from above via the air. In both

Fig. 1. Length of shoots and ethylene concns at different places in a box planted with healthy and Fusarium-infected tulip bulbs. No. 1 to 9 indicate the places where gas was sampled. Planting date was March 3; Ethylene determinations were made 3, 9, 17, and 34 days after planting. The diseased bulbs were planted at places 3 and 7 and are indicated by the arrows.
experiments the growth of the shoots and roots was totally inhibited (Fig. 3). From these experiments it could also be concluded that the growth inhibition is reversible. After termination of the ethylene administration, which lasted 4 weeks, elongation growth was resumed. The plants did not flower, however, because the flower buds became blasted during the treatment with ethylene.

In addition to growth retardation and flower blasting we observed several other phenomena. The 3 most important being: roots had a twisted appearance and the shoots grew curved; there was an abundant development of root hairs (Fig. 4), which normally occur only sporadically or not at all in tulips; an increase in the average root diam from 0.60 to 0.90 mm was detected.

Smith and Scott Russell (13) showed that ethylene concns up to 10 ppm can occur in the soil atm as a consequence of anaerobic conditions. Our experiments indicate that concns at least as large can occur in the presence of tulip bulbs infested with Fusarium. Anaerobic conditions could not have played a part in our experiments because the bulbs were planted at a depth of only 7 cm in boxes containing loose sandy soil. The influence of anaerobic conditions on the ethylene production of Fusarium-infected bulbs is not known.

The present findings in tulips fully support the suggestion of Radin and Loomis (10), who studied the inhibitory effect of ethylene on the growth of radish roots, that ethylene may play an important part in the ecology of the soil environment. It is evident that under the influence of ethylene in the soil atm tulips show an inhibition not only of root growth but also of shoot growth. The phenomena of twisted and curved roots and the development of numerous root hairs are in agreement with the observations on roots of Triticum and Plasnum made by Roberts (11) and Chadwick and Burg (3). They found that roots growing under influence of ethylene swell and twist and develop a large number of root hairs a short distance from the growing point. The phenomena of reduced shoot growth and blasting of the flower buds agree with the observations of Hitchcock et al. (6) who studied the effect on tulips of illuminating gas containing ± 3% ethylene.

Although it is known that blasting of flower buds can occur in tulips upon stagnation of root growth caused, for example, by a hard skin, a clod of manure, or pathogens (Pythium), it seems more likely that in our experiments bud blasting was caused directly by ethylene. Blasting of flower buds and inhibition of shoot growth under the influence of ethylene can be observed in tulip bulbs before planting even when roots have not yet developed (9).

In the experiments ethylene was present in clearly detectable amounts at a distance of about 25 cm from the diseased bulbs and within this distance all flowers became blasted. The radius of action of the infected bulbs will be determined by the conditions controlling horizontal diffusion of the gas. Soil structure and air porosity strongly influence this diffusion process (1). It is not excluded that at distances greater than 25 to 35 cm from the source of ethylene, biological active concns can occur as a consequence of silting up of the surface layers of the soil. Of course, the planting depth of the diseased bulbs will also affect the distance at which biological active concentrations can occur.

Radin and Loomis (10) and Chadwick and Burg (4) showed that higher concns of CO2 can counteract certain effects of ethylene. The influence of CO2 and other environmental factors on the reaction of tulips to ethylene has not yet been investigated.

Literature Cited

Fig. 2. Tulip plants, removed from a box in which Fusarium-infected bulbs had been planted at 2 places (arrows), showing the inhibition of root and shoot growth.

Fig. 3. Influence of applied ethylene (6 ppm) on shoot growth during the first 4 weeks after planting.

Left: Control plants (air passed through the soil).
Right: Plants from soil through which ethylene had been passed.

Fig. 4. Photomicrograph of freehand cross-section of tulip root showing numerous root hairs. Bulbs were exposed to ethylene (6 ppm) for 4 weeks directly after planting.