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# Effects of Fusicoccin on Intact Cotton Plants (*Gossypium hirsutum* L.)

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**Abstract.** Fusicoccin (FC) was applied as a spray to shoots of intact field- and glasshouse-grown cotton plants. Distortions of shoot morphology resulted. Stems and petioles of FC-treated plants were irregular in diameter and twisted, whereas leaf laminae were curled and crinkled. Shoot elongation was inhibited by FC; the effect was dependent upon the concentration and timing of the applications.

**Key Words.** Fusicoccin—*Gossypium*—Morphology

The fungal toxin fusicoccin (FC) has been studied widely in plant physiology because of its dramatic effects on plant cells (Marrè 1979). A principal action of FC appears to be activation of the plasma membrane $H^+$-ATPase (Johansson et al. 1993), and the resultant acidification of the cell wall is believed to cause wall loosening leading to cell enlargement (Rayle and Cleland 1992). However, many cellular processes are affected at least indirectly by FC (Cerana et al. 1989, Marrè 1979, Müller et al. 1991, Xu et al. 1992), so the consequences of FC application to whole plants are difficult to predict.

Most experiments on FC have used excised plant tissues, and it has been pointed out that there are few reports on FC responses in intact plants (Lavee and Cleland 1993). The present paper extends the range of plant materials tested for response to FC. We describe the results of FC application to intact field- and glasshouse-grown cotton plants.

## Materials and Methods

### *Plants*

The following lines of cotton (*Gossypium hirsutum* L.) from the genetic collection of the University of Tashkent, Uzbekistan, were used in these experiments: L-20, 458, 463, 501, 501-1, 511, 525, 601, 602, 650, 653, 669, 681. Progeny of crosses between lines were also tested: $F_1$ (501 × 653), $F_1$ (501 × 650), $F_1$ (601 × 501), $F_1$ (601 × 525), $F_1$ (525 × 653). This wide range of genotypes, which included agricultural cultivars plus some leaf shape and dwarf mutants, was examined in case some genotype-specific responses were to be found. However, the tested genotypes responded similarly with respect to the features described in the present paper.

### *Fusicoccin Treatments*

Field trials were carried out in an irrigated plot at the University of Tashkent. Plants were sown in late April 1995 for Experiments A–C and in the second week of May 1992 for Experiment D. The shoot apical region, including the three youngest leaves, was sprayed with FC at the times and concentrations indicated in the Results and Discussion section. Fusicoccin was a gift of Professor G. S. Muromtsev, Institute of Agricultural Biotechnology, Moscow. All spray solutions, including controls, contained 1% ethanol and 0.025% Tween 80 (Sigma). Stem heights from cotyledons to apex were measured at each time of spraying. The measurements in Table 1 were made 13 weeks after sowing. Statistical significance was tested at the 5% level by analysis of variance and Duncan's multiple range test (Duncan 1955). The plant in Fig. 1 was grown in Aberystwyth, UK, in a glasshouse heated to a minimum of 18°C, with daylength supplemented to 16 h by 1,000-watt mercury vapor lamps. Its appearance was similar to that of the field plants.

## Results and Discussion

Fusicoccin caused marked symptoms when applied as a spray to the growing regions of shoots of whole cotton plants in the field (Tashkent, Central Asia) or glasshouse (Aberystwyth, UK). Applications of FC ($10^{-4}$ M) inhibited stem elongation and induced morphologic distortions of the shoot as shown in Fig. 1. The stems and petioles of FC-treated plants exhibited irregular swelling and twisting, with pronounced development of surface patches of phellem tissue. Leaves of treated plants were curled with crinkled laminae. These symptoms tended to be localized to the shoot regions directly sprayed with FC; branches screened from the spray retained normal morphology. This is in accordance with the report of Radice et al. (1980) that transport of [$^3$H]FC occurred

**Abbreviation:** FC, fusicoccin.

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**Fig. 1.** Effects of FC on intact cotton plant. Growing regions of the shoot were sprayed weekly with FC ($10^{-4}$ M) for 2 months, commencing when the plant was 1 month old.

mainly by transpiration-dependent mass flow in the xylem, with simple diffusion in other tissues.

The results of field trials of FC on cotton plants in Tashkent are summarized in Table 1, as the mean height of FC-treated plants as a percentage of controls. Experiments A, B, and C were conducted simultaneously in the same field plot. In Experiment A, plants were grown during the normal season in Tashkent, with sowing at the end of April. Fusicoccin ($10^{-4}$ M) was sprayed over the growing apical parts, at weekly intervals commencing after 6 weeks. At the flowering stage (13 weeks) FC-treated plants were about 75% of the mean height of control plants. The smaller stature of the FC-treated plants was because of reduced internode elongation; the mean numbers of internodes per FC-treated plant were not significantly different from those of the controls. Wilting of leaves was not observed following FC treatment, despite the known activity of this compound as a wilt toxin (Van Alfen 1989). Treated plants were generally sturdy and healthy apart from the morphologic distortions described above.

In Experiment B, plants were treated with FC at $10^{-7}$ M at the same times as in Experiment A. This lower concentration of FC inhibited stem growth to a lesser extent.

**Table 1.** Height of FC-treated field plants as percent of controls, averaged for several cotton lines (5–10 plants tested per line). The number in parentheses is the number of lines in which FC caused a height reduction significant at 5%. Experiments A–D are described in the text.

| Field trial | Mean % of control height (±S.E.) | No. of lines tested |
|---|---|---|
| Experiment A | 74.8 ± 3.0 | 8 (6) |
| Experiment B | 85.1 ± 4.7 | 8 (5) |
| Experiment C | 82.9 ± 4.2 | 10 (7) |
| Experiment D | 62.5 ± 2.7 | 10 (10) |

In Experiment C, weekly spraying with FC ($10^{-4}$ M) commenced at a later stage of development than in Experiment A, namely the onset of flower bud formation after 8 weeks. This later treatment inhibited stem growth to a lesser extent.

Experiment D was a separate field trial during a different season, with a later sowing date in the 2nd week of May so that the seedlings were exposed to higher daily temperatures than in Experiments A–C. Plants were sprayed with FC ($10^{-4}$ M) at 10-day intervals commencing 6 weeks after sowing. In this trial, inhibition of growth was more marked than in Experiment A. Other experiments confirmed that these cotton genotypes exhibited the typical, widely reported, tissue expansion response (Marrè 1979) when FC was tested on excised seedling tissues (results not included).

Few comparable observations on the effects of FC on intact plants have been reported previously. Lavee and Cleland (1993) applied FC through the transpiration stream to bean shoots with the roots removed. These procedures caused inhibition of leaf growth and bending of stems. It was suggested that this stem bending might have been due to a non-uniform distribution of cellular capacity to undergo acid-induced wall loosening in growing plant tissues. This hypothesis could also explain our observations of severe morphologic distortions in FC-treated shoots of whole plants.

In addition to the morphologic distortions probably caused by cell expansion effects of FC, the multiple consequences of FC action on stomatal aperture, cytoplasmic pH, transport processes, etc. are likely to have modified many aspects of the metabolism and physiology of the treated plants (Cerana et al. 1989, Marrè 1979, Müller et al. 1991, Van Alfen 1989, Xu et al. 1992). The full explanation of the inhibitory effect of FC will therefore be complex.

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