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Role of Plant Growth Regulators in Host-Pathogen Relationships*

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Abstract. The effect of indol-3-ylacetic acid, gibberellic acid, kinetin, abscisic acid and Ethrel on the growth of mycelium, sporulation and germination of spores of *Fusarium culmorum* of different pathogenicity to wheat seedlings was studied. The production of gibberellins, auxins, cytokinins, ethylene and growth inhibitors by these isolates was determined as well. It has been found that most pronounced and explicit effect on growth and development in fungi was produced by Ethrel which strongly inhibited these processes. ABA proved to be a strong growth and development stimulator, though to a different extent in different isolates. GA_3 strongly stimulated sporulation and spore germination in some isolates. The effect of IAA and K on growth and development in fungi was slight. More sensitive to growth regulators were the fungi in earlier stages of growth. No correlation between the pathogenicity of the isolates and their ability to produce growth regulators as well as between their susceptibility to exogenous growth substances in the processes of fungal growth and development was stated.

Our knowledge of the role of plant growth regulators in host-pathogen relationships is not only scarce but also controversial (MICHNIEWICZ 1982).

Some light has been thrown on this problem by the results of experiments carried out in our laboratory on three isolates of *Fusarium culmorum* showing different degrees of pathogenicity to wheat seedlings. The capability of these fungi of synthesizing growth regulators has been determined and the effect of exogenous growth regulators on the growth and development of the fungi has been studied. The results obtained in these experiments have been published in five papers (MICHNIEWICZ *et al.* 1983 a, b, 1984 a, b, MICHNIEWICZ and ROŻEJ 1984), each of which is devoted to a detailed discussion of only one growth regulator. The papers also include all the available literature concerning the problem.

The purpose of the present paper is to discuss the problem using the data given in the above publications and to formulate conclusions concerning the direction of further studies.

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MATERIAL AND METHODS

Three isolates of *Fusarium culmorum* (W.G.Sm.) Sacc. of different pathogenicity to wheat seedlings (F1 — strongly, F2 — rather strongly and F3 — weakly pathogenic) were used.

The fungi were grown in darkness at 22 °C in liquid or on agar Czapek-Dox medium containing GA_3, IAA, K, ABA at concentrations of 10^{-9} to 10^{-5} M or Ethrel at concentration of 1 to 1000 mg l^{-1}. The growth regulators were filter-sterilized (Millipore, pore size 0.47 μm). On the agar medium the surface of colonies of fungi was measured daily during 5 days. Number of spores of mycelium grown in liquid Czapek-Dox medium was studied in the Thom's chamber. Spores were germinated in the liquid Czapek-Dox medium and counted after 5 h considering 500 spores in each variant of experiment.

Growth regulators: auxins, gibberellins, cytokinins and growth inhibitors were determined in culture filtrates after 14 d of incubation in liquid Czapek-Dox medium. In the case of auxins culture filtrates contained tryptophan (200 mg l^{-1}). For the determination of ethylene production the fungi were grown for 4 d in the liquid Czapek-Dox medium (see Table 1) containing glucose (5 g l^{-1}) instead of saccharose and methionine (5 g l^{-1}) as the precursor for ethylene production (Lynch and Harper 1974). Growth substances were separated by column chromatography on a Sephadex LH-20 or by gas chromatography. Detailed data on the extraction, fractionation and purification of these substances are to be found in the papers of Michniewicz and Galoch (1974) and Michniewicz *et al.* (1983 a, b, 1984 a, b).

All experiments were performed in triplicate with 5 repetitions in each experiment. Significant differences (LSD) were estimated at $P = 0.001$, 0.01 and 0.05.

Table 1

Production of growth substances by isolates of *Fusarium culmorum* of different pathogenicity to wheat seedlings (after 2 weeks of growth in liquid Czapek-Dox medium*)

Growth substance	Reference substance	Quantity of growth substance		
		Isolate F1	Isolate F2	Isolate F3
Auxin[1])	IAA	1.5	72.8	0.9
Gibberellin[1])	GA_3	9.2	30.1	25.6
Cytokinin[1])	BAP	0.23	0.07	0.06
Growth inhibitors[2])	ABA	4.58	2.21	3.67
Ethylene[3])	—	0.80	0.32	0.68

[1]) in μg of reference substance per 100 g of dry mass of mycelium.
[2]) in ng of reference substance per 100 g of dry mass of mycelium.
[3]) in μl $l^{-1}mg^{-1}$ of dry mass of mycelium.
* for determination of ethylene production the fungi were grown on agar medium for 9 days and then transferred into the liquid medium where cultivated for 4 days.

Abbreviations used: ABA = abscisic acid; BAP = 6-benzylaminopurine; GA_3 = gibberellic acid; IAA = indol-3-ylacetic acid; K = kinetin.

RESULTS AND DISCUSSION

All fungi were capable of synthesizing auxins, gibberellins, cytokinins, ethylene and growth inhibitors (but not ABA). These data (Table 1) clearly indicate a lack of correlation between the degree of pathogenicity of the isolate and its capability of synthetizing growth substances.

The most pronounced and explicit effect on growth and development in fungi was exhibited by Ethrel — a compound releasing ethylene — which strongly inhibited these processes (Figs. 1—3). ABA proved to be a strong growth and development stimulator, though to a different extent in different isolates. GA_3 strongly stimulated sporulation and spore germination in some isolates. The effect of IAA and K on growth and development in fungi was slight. Applied in the lowest concentrations, these compounds slightly stimulated, and in the highest concentrations slightly inhibited these processes.

The results obtained in these experiments explicitly testify that the effect of growth regulators on growth and development in fungi depended on both the concentration of the regulator and the isolate.

This effect also depended on the development stage of the fungus. Measurements of mycelium mass were taken daily for 5 d, and the most sensitive to these compounds proved to be the fungi in the early stages of development (Table 2). This fact points to the fungal capacity for adaptation to life in a medium containing plant hormones, even in comparatively high concentrations.

The results of the present experiments also indicate explicitly that the effect of growth regulators on growth and development in fungi did not correlate with the degree of their pathogenicity.

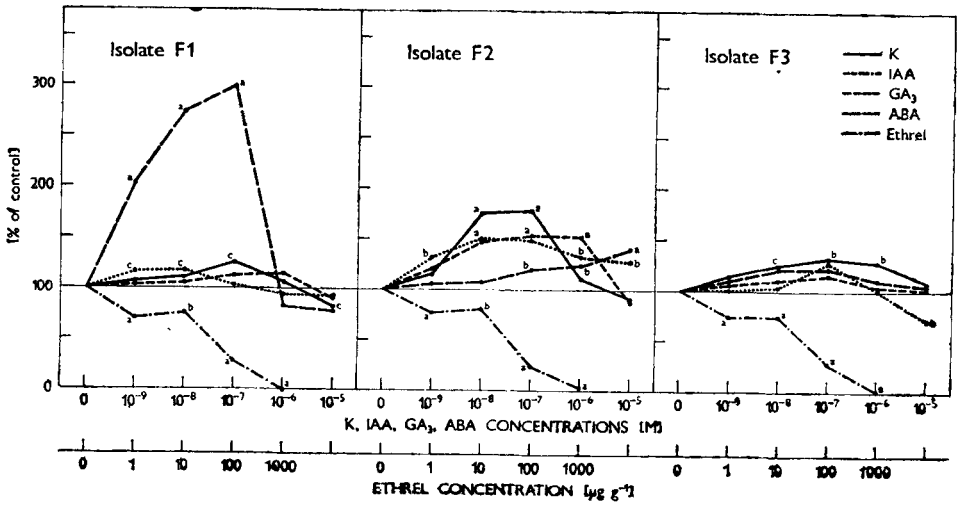

Fig. 1. Effect of plant growth regulators on growth of isolates of *Fusarium culmorum* on Czapek-Dox agar medium measured after 2 days of cultivation (% of the control).
Differences significant in relation to control at: a — $P = 0.001$, b — $P = 0.01$, c — $P = 0.05$.

It is particularly interesting to compare the effect of ethylene on growth and development in fungi with that of ABA. As follows from reports in the literature, the amount of both these hormones in plant increases under stress conditions and after mechanical tissue injury, and their level in diseased plants is generally higher than in healthy ones (ARCHER and HISLOP 1975, PEGG 1976a,b,c,d). In our studies, however, the effects of these two hormones on growth and development in fungi were opposed to each other.

The facts demonstrated in this paper, *i.e.*: 1. the opposite effect of ethylene and ABA (hormones whose amount in plant is generally increased by pathogens, under stress conditions and after mechanical tissue injuries) on growth and development in fungi; 2. lack of correlation between the degree of pathogenicity and the fungal capacity for growth regulators production; 3. lack of correlation between the degree of pathogenicity and the response of fungi to exogenous growth and development regulators, and finally 4. decrease in the fungal susceptibility to growth regulators with age, suggest that the growth substances do not play any significant role in the mechanisms of pathogenesis.

So far, however, there is a lack of information on events which may occur on the molecular level in the initial stages of interactions between plant cell and the pathogen. Information relating to this problem seems indispensable

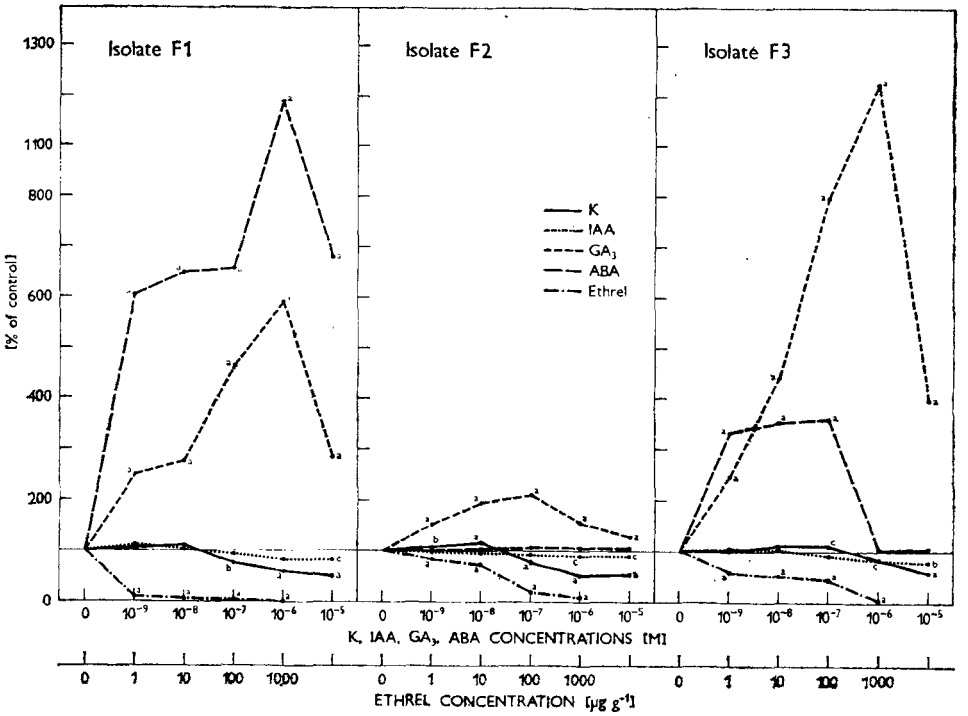

Fig. 2. Effect of plant growth regulators on sporulation of isolates of *Fusarium culmorum* (% of the control).
Differences significant in relation to control at: a — $P = 0.001$, b — $P = 0.01$, c — $P = 0.05$.

TABLE

Effect of ABA and Ethrel on growth of *Fusarium culmorum* (isolate F1) on Czapek-Dox agar during 5 days of cultivation (% of the control)

Growth substance	Concentration	Time [d]				
		1	2	3	4	5
ABA	10^{-8}M	420.8	272.2	157.0	103.3	100.0
	10^{-7}M	480.4	298.7	170.4	104.4	100.0
Ethrel	10 mg l^{-1}	71.9	82.2	81.6	88.1	100.6
	100 mg l^{-1}	28.9	29.5	22.6	54.5	55.7

to understanding the role of growth regulators in the plant-pathogen interaction.

The results of the present experiments also suggest that Ethrel could be applied in agricultural practice to prevent and fight plant diseases caused by fungal pathogens. It must be borne in mind, however, that not all fungal pathogens are inhibited by Ethrel, as are the isolates of *Fusarium culmorum* (DEHNE and SPENGLER 1982).

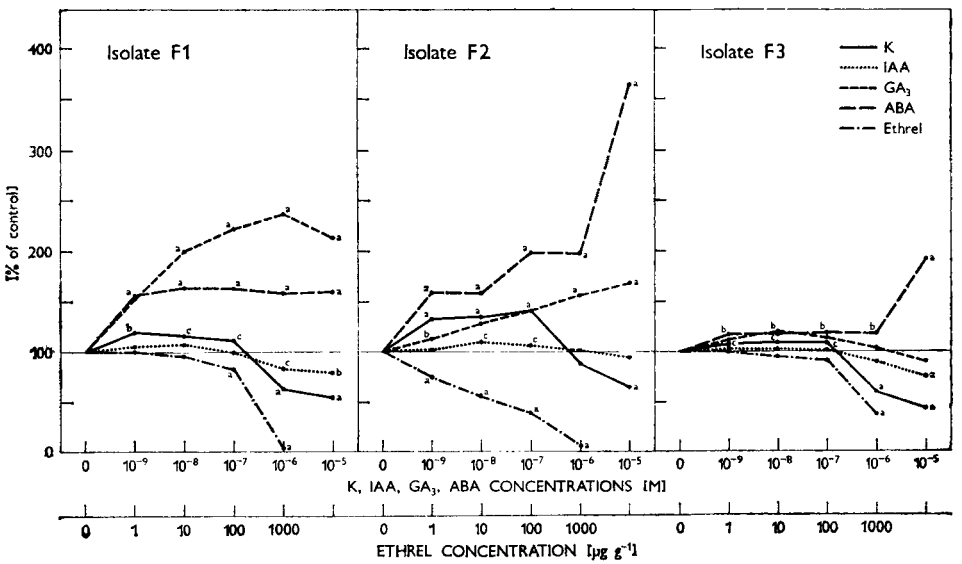

Fig. 3. Effect of plant growth regulators on germination of spores of isolates of *Fusarium culmorum* (% of the control).
Differences significant in relation to control at: a — $P = 0.001$, b — $P = 0.01$, c — $P = 0.05$.

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