Systemic Induced Resistance

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Abstract

Biotic and abiotic agents may induce resistance in plants against pathogens. Abiotic agents may be synthetic or natural. The natural, non-protein amino acid BABA (DL-β-aminobutyric acid) induces systemic resistance in crop plants against pathogens. Dry, killed mycelia of *Penicillium chrysogenum* (DM) induces local resistance in plants against soil-borne pathogens. The activity of BABA and DM are described here in detail. Both products were shown to effectively control plant disease in nature.

Keywords: systemic induced resistance; local induced resistance; immunization; disease control

INTRODUCTION

Biotic, as well as abiotic, agents may induce local and/or systemic resistance in plants against disease. Our previous studies with biotic agents showed that a primary infection of tobacco stems with *Peronospora tabacina* protected the foliage against challenge infection with that pathogen (COHEN & KUĆ 1981); a primary infection of avocado roots with *Phytophthora parasitica* protected the roots against *Phytophthora cinnamomi* (DOLAN *et al.* 1986); primary infection of cucumber cotyledons with tobacco necrosis virus (TNV) protected the true leaves from *Sphaerotheca fulinginea* (BASHAN & COHEN 1983) and primary infection of the bottom leaves of potato with *Phytophthora infestans* protected the upper leaves from that pathogen (COHEN *et al.* 1991). Other studies with abiotic agents showed that polyunsaturated fatty acids (PUFAs), such as arachidonic acid and eicosapentaenoic acid, applied to the bottom leaves of potato induce resistance in upper leaves against *P. infestans* (COHEN *et al.* 1991); fish oils, by themselves having no antifungal activity, sprayed onto the foliage of potato protected against *P. infestans* (COHEN, US Patent 5,494,641, 1995); dry fungal biomass of *Penicillium chrysogenum* (DM) applied to the soil or its water extract applied to the roots induce resistance against wilt diseases in melon and cotton (DONG & COHEN 2001, 2002a,b) and water extracts of DM applied to the foliage or roots of tomato protected the foliage against *P. infestans* (MOSINGER, WO Patent 97/45018). We also showed that DL-β-aminobutyric acid (BABA) induces systemic resistance against a broad spectrum of plant pathogens (COHEN 2002).

In this review I describe the systemic resistance induced by BABA and the local resistance induced by DM.

Resistance induced by BABA

BABA is a non-protein amino acid. GAMLIEL & KATAN (1992) discovered BABA in root exudates of tomato. We have detected BABA (also AABA = DL-2-aminobutyric acid and GABA = 4-aminobutyric acid) in normal tomato leaves (COHEN & DITHELM-SCHALBERGER, unpubl.). BABA, therefore, may be considered a natural amino acid. VAN ANDEL (1958) was the first to report that BABA had a therapeutical effect in tomato against *P. infestans*. PAPAVIZAS and DAVEY (1963) showed that BABA (as well as β-methyl-threo aspartic acid) induced resistance against *Aphanomyces eutiches* in peas.

Today we know that BABA protects about 50 crops, including cereals, vegetables and trees against a broad spectrum of pathogens, including TMV, bacteria, oomycetes, fungi and nematodes (COHEN 2002).

BABA is a phloem mobile compound. It may translocate from treated leaves both acropetaly and basibetaly, and from treated roots – acropetaly.

Only a small fraction of BABA applied to the leaf surface is taken up into the mesophyll. Transport into the plant cell is probably facilitated by a transporter (SCHWACKE *et al.* 1999). Most BABA taken up by the tissue remained unmetabolized.

BABA has no antimicrobial activity *in vitro*. Spore germination and mycelial growth take place in media supplemented with as much as 4000 μg/ml of BABA. In contrast, when supplied to leaf tissue, e.g. leaf discs of tomato, about 25 μg/ml are sufficient to induce complete resistance against *P. infestans*. When sprayed onto plants, higher concentrations are required to fully protect against disease due to the poor uptake (COHEN 1994b).

BABA was shown to effectively control diseases also in the field, e.g. downy mildew in grapevines (REUVENI *et al.* 2001), moldy core in apple (REUVENI & COHEN unpubl.), late blight in potato and tomato and sudden wilt in melon (COHEN unpubl.).

The mode of action of BABA varies according to the pathosystems. In the tobacco-downy mildew system (COHEN 1994a) and the Arabidopsis-downy mildew system (ZIMMERLI *et al.* 2000) BABA operates via the salicylic-acid-independent signaling pathway as it was fully protective in NahG mutant plants which fail to produce salicylic acid. However in the TMV-tobacco system (SIEGRIST *et al.* 2000) and the *Arabidopsis – Pseudomonas syringe* system (ZIMMERLI *et al.* 2000) BABA operated via the salicylic-acid-dependent signaling pathway. In the *Arabidopsis – Botrytis cinerea* system BABA operated via the jasmonate-ethylene signaling pathway (ZIMMERLI *et al.* 2001).

BABA was shown to potentiate (prime) a treated tissue to rapidly and effectively respond to infection. Thus, *Arabidopsis* plants treated with BABA accumulate PR proteins faster and in higher amounts as compared to untreated plants, upon inoculation (JAKAB *et al.* 2001; ZIMMERLI *et al.* 2000). Unlike other SAR compounds, which require 2–4 days to activate the plant against disease, BABA may be applied at time 0 or even 1–2 days after inoculation. Such curative effect of BABA was shown in tomato (COHEN 1994b), tobacco (COHEN 1994a) and grape (COHEN *et al.* 1999).

BABA induces resistance against disease when applied to the foliage, to the roots or to the seed. Soaking seed of sunflower in BABA protected against *Plasmopara halstedii* (COHEN unpubl.) and of pearl millet against *Sclerospora graminicola* (SHAILASREE *et al.* 2001). In the latter case protection lasted for 60 days and was accompanied with a yield increase.

BABA induces a variety of defense compounds, depending on the host, pathogen and mode of application. Amongst these compounds are PR-proteins, callose, lignin, H_2O_2, phenolics and phytoalexins (COHEN 2002). Of the two enantiomers of BABA, R and S, only R is protective (COHEN 1994a).

BABA-mediated resistance may be inhibited by its isomers AABA and GABA and by L-proline. This inhibition results from competition during uptake (OVADIA & COHEN unpubl.).

BABA synergize with other SAR compounds (e.g. BTH) and with fungicides (e.g. metalaxyl) in protecting for example, tobacco against *Peronospora tabacina* (COHEN 2002). It also synergizes with mancozeb in controlling blight in potato and tomato and downy mildew in cucumbers (COHEN, US Patent 6,414,019, July 2002).

BABA was not toxic to rats when supplied in the drinking water (1%) for 30 days (COHEN, BUGANIM & BITON unpubl.).

Resistance induced by DM

DM is a waste product of the pharmaceutical industry. It is produced from dry, killed mycelia of *Penicillium chrysogenum*. The mycelia are heated to 110°C for 4 h and contains no residual penicillin. DM contains about 90% organic matter with N:P:K content (%) of 7:1:2. Our studies showed that DM is an effective organic fertilizer. When applied to soil in microplot experiments significant increments in yield were obtained in potato, tomato, wheat, corn and cotton (Figure 1). DM and water extracts of DM exhibited no antimicrobial activity *in vitro*. However, when supplied to soil they protected plants against soil-borne diseases. Adding DM to the soil protected melon against all 4 races of *Fusarium oxysporum* f.sp. *melonis* (DONG & COHEN 2001). Uninoculated treated plants exhibited a rapid (within 12 h) increase in peroxidase activity in the root tissue. DM and DM extracts protected cotton against *Fusarium vasinfectum* (DONG & COHEN 2002b) *Verticillium dahliae* (DONG & COHEN 2002a). Such treatments were associated with elevated peroxidase activity not only in the root but also in the hypocotyls and first leaves. This pathogen colonized the roots of protected and unprotected plants to a similar extent but colonization of the hypocotyl was strongly suppressed in treated, protected plants (DONG & COHEN 2002a). Current field data (unpublished) show that DM protected cotton against *V. dahliae*

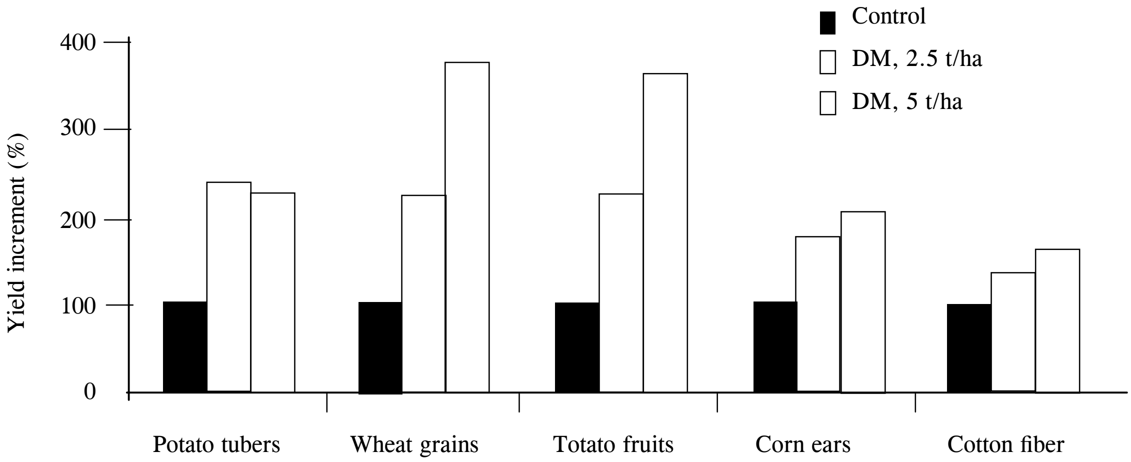

Figure 1. The effect of DM on yield of crop plants under field conditions

and *F. vasinfectum* (SAIDKANIMOV & COHEN); Corn against *Fusarium moniliforme* (PING & COHEN); and cucumber or tomato against the root-knot nematode *Meloidogyne javanicum* (GOTLIEB, BEN-DANIEL, OKA & COHEN).

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