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Plants in the Pink: Cytokinin Production by *Methylobacterium*

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Bacteria of the genus *Methylobacterium* are well-studied examples of facultative methylotrophs. These bacteria are classified as α-proteobacteria and are capable of growth on methanol and methylamine as well as on a variety of C_2, C_3, and C_4 compounds (8). *Methylobacterium* strains are commonly found in soils, as well as on the surfaces of leaves of a wide variety of plants (1). Because of their distinctive pink pigmentation, they are sometimes referred to as PPFMs (pink-pigmented facultative methylotrophs). Evidence exists that these bacteria utilize methanol emitted by the stomata of plants (9), but the details of their relationship to plants has been unclear. Are *Methylobacterium* strains commensal bacteria, or do they communicate with plants in a more intimate relationship? A number of reports suggest that *Methylobacterium* strains are more than passive passengers on plant leaves. For instance, they have been shown in some cases to stimulate seed germination and plant development, possibly by production of phytohormones (2, 3, 4), and it has been reported that one strain produces the cytokinin zeatin (5) while others have been reported to produce indole acetic acid (6). In addition, *Methylobacterium* strains have been suggested to contribute to the flavor of strawberries (12) and have been localized as endosymbionts within cells of the buds of Scotch pine (*Pinus sylvestris*) (10). One nonpigmented *Methylobacterium* strain has been shown to form a root-nodulating nitrogen-fixing symbiosis with a legume (11). A partial genome sequence of *Methylobacterium extorquens* AM1 is available (http://pedant.mips.biochem.mpg.de/), which reveals a number of open reading frames with significant identity to genes involved in plant association in rhizobia and *Agrobacterium* (M. Lidstrom, unpublished results). Therefore, at this point numerous indications exist that these PPFMs interact with plants, but the biochemical and genetic details of those interactions have remained elusive.

In this issue, Koenig et al. (7) present a set of studies that represents an important step in understanding the molecular basis of *Methylobacterium*-plant interactions. They show that four different *Methylobacterium* strains representing leaf isolates and a type *M. extorquens* strain all produce the cytokinin *trans*-zeatin at low levels in pure culture and excrete it into the culture medium. Biochemical and genetic evidence is presented suggesting that the *trans*-zeatin is not synthesized de novo but instead is derived from tRNA. This result is surprising, since so far the tRNA-derived zeatin from bacteria and plants has been restricted to the *cis* isomer. Is the low-level production of *trans*-zeatin observed in these strains sufficient to have an effect on plants? Surprisingly, the *Methylobacterium*-specific stimulation of seed germination that has been described in the past (3, 4) was unaffected in a mutant that is incapable of producing *trans*-zeatin. Thus, the answer to this question is still outstanding, as is the source of the stimulation effect itself. However, the results presented by Koenig et al. provide mechanistic evidence for cytokinin production by *Methylobacterium* strains, leading the way for future studies of the *Methylobacterium*-plant relationship. In addition, this evidence that a commensal bacterium produces a phytohormone via a previously unknown route provides new insights into the role of commensal plant bacteria in general.

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REFERENCES

1. **Corpe, W. A.** 1985. A method for detecting methylotrophic bacteria on solid surfaces. J. Microbiol. Methods **3:**215–221.
2. **Corpe, W. A., and D. V. Basile.** 1982. Methanol-utilizing bacteria associated with green plants. Dev. Ind. Microbiol. **23:**483–493.
3. **Holland, M. A., and J. C. Polacco.** 1992. Urease-null and hydrogenase-null phenotypes of a phylloplane bacterium reveal altered nickel metabolism in two soybean mutants. Plant Physiol. **98:**942–948.
4. **Holland, M. A. and J. C. Polacco.** 1994. PPFMs and other covert contaminants: is there more to plant physiology than just plant? Annu. Rev. Plant Physiol. Plant Mol. Biol. **45:**197–209.
5. **Ivanova, E. G., N. V. Doronina, A. O. Shepeliakovskaia, A. G. Laman, F. A. Brovko, and Yu. A. Trotsenko** 2000. Facultative and obligate aerobic methylobacteria synthesize cytokinins Mikrobiologiya **69:**764–769. (In Russian.)
6. **Ivanova, E. G., N. V. Doronina, and Y. A. Trotsenko.** 2001. Aerobic methylobacteria are capable of synthesizing auxins. Microbiology **70:**392–397.
7. **Koenig, R. L., R. O. Morris, and J. C. Polacco.** 2002. tRNA is the source of low-level *trans*-zeatin production in *Methylobacterium* spp. J. Bacteriol. **184:**1832–1842.
8. **Lidstrom, M. E.** The aerobic methylotrophic bacteria. *In* M. Dworkin (ed.), The prokaryotes, in press [online]. Springer-Verlag, New York, N.Y.
9. **Nemecek-Marshall, M., R. C. MacDonald, J. J. Franzen, C. L. Wojciechowski, and R. Fall.** 1995. Methanol emission from leaves: enzymatic detection of gas-phase methanol and relation of methanol fluxes to stomatal conductance and leaf development. Plant Physiol. **108:**1359–1368.
10. **Pirttila, A. M., H. Laukkanen, H. Pospiech, R. Myllyla, and A. Hohtola.** 2000. Detection of intracellular bacteria in the buds of Scotch pine (*Pinus sylvestris* L.) by in situ hybridization. Appl. Environ. Microbiol. **66:**3073–3077.
11. **Sy, A., E. Giraud, P. Jourand, N. Garcia, A. Willems, P. de Lajudie, Y. Prin, M. Neyra, M. Gillis, C. Boivin-Masson, and B. Dreyfus.** 2001. Methylotrophic *Methylobacterium* bacteria nodulate and fix nitrogen in symbiosis with legumes. J Bacteriol. **183:**214–220.
12. **Zabetakis, I.** 1997. Enhancement of flavour biosynthesis from strawberry (*Fragraria ananassa*) callus cultures by *Methylobacterium* species. Plant Cell Tissue Organ Cult. **50:**179–183.

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