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Bose-Einstein condensation in a gas of sodium atoms

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Published in:
Physical Review Letters

DOI:
[10.1103/PhysRevLett.75.3969](https://doi.org/10.1103/PhysRevLett.75.3969)

[Link to publication](#)

Citation for published version (APA):

Davis, K. B., Mewes, M. O., Andrews, M. R., van Druten, N. J., Durfee, D. S., Kurn, D. M., & Ketterle, W. (1995). Bose-Einstein condensation in a gas of sodium atoms. *Physical Review Letters*, *75*(22), 3969-3973. <https://doi.org/10.1103/PhysRevLett.75.3969>

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Plants may talk, but can they hear?

Interest in interplant communication via airborne signals has recently been revived. Bruin *et al.*¹ review evidence for signalling and its role in plant defense. We find the evidence tantalizing but, as yet, inadequate to support a 'talking tree' hypothesis. No one has demonstrated that airborne signals (e.g. methyl jasmonate, ethylene) produced from wounded plants occur in sufficient quantities to be detected by undamaged plants under realistic environmental conditions. This criterion of recipient detection is, to our minds, more important than demonstrating that damaged plants produce biologically active volatiles.

A few simple calculations reveal a large discrepancy between signal release from wounded plants and the sensitivity of undamaged receiver plants, given signal dilution in air. Consider 5×10^3 g wounded leaves in 1 m^3 , releasing ethylene into an air stream that passes into an adjacent 1 m^3 containing an undamaged receiver plant. Ethylene production by undamaged plants ranges from 5×10^{-11} – 5×10^{-10} g⁻¹ leaf h⁻¹, increasing several-fold on wounding². Assume the maximum release rate increases 100-fold, and all leaves are wounded. This would produce 2.5×10^{-4} h⁻¹ into 1 m^3 . Suppose a very gentle breeze of 0.1 m s^{-1} was blowing (c.f. mean wind speeds of 4 m s^{-1} in the UK). Thus, in 1 h, 3.6×10^{11} of air containing 2.5×10^{-4} ethylene will have passed to the receiving plant, a dilution of $>10^8$, and an effective ethylene concentration of only 7×10^{-9} l⁻¹ air. It is generally accepted² that ethylene is physiologically active at 10^{-7} – 10^{-6} l⁻¹, at least two orders of magnitude higher than we calculate given very generous estimates of ethylene release and wind speed. Similar calculations (not shown) suggest that signal concentrations are, at best, only likely to be sufficient to result in physiological responses in undamaged plants under very rare circumstances – perhaps large areas of vegetation being heavily attacked (e.g. an outbreak) at very low wind speeds (e.g. below the top of the canopy).

It is clear that if wounded plants produce ubiquitous signals that are also produced by unwounded plants, the concentration in air will have to be significantly higher than that released by unwounded plants (as well as being at or above the physiological response threshold). If this is not so, then unwounded plants will be unable to distinguish signal from noise, and responses will not occur. The signal-to-noise problem could be overcome if plants used specific rather than ubiquitous chemical signals. However, this would require the capacity to specifically detect a vast array of compounds at very low concentrations. This seems unlikely and there is no evidence to support this.

It is perhaps inevitable³ that some compounds from plants will evoke plant physiological responses when applied in high doses. Such evidence is not sufficient to ascribe a role. Support for the hypothesis that airborne signals can induce plant defenses awaits evidence that

plants listen, even if talking seems more appealing at present.

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Reply from J. Bruin, M.W. Sabelis and M. Dicke

We can smell from quite a distance that the small lawn opposite our lab in Amsterdam is being mown. If we can smell this, why would the grass plants under our window not be able to? Even tiny insects, herbivores as well as predators and parasitoids, react to (damage-related) plant volatiles^{1–3}. If they are able to detect the airborne signals, why would plants not be able to? No *a priori* reason comes to mind. Indeed, as pointed out by Firm and Jones, damage-related signals will be diluted, increasingly so with increasing distance from the source. Moreover, changing wind-directions will ensure that undamaged plants will only be briefly exposed to the low concentrations. But is this necessarily a problem? Plants are much larger than insects and therefore receive more signal molecules. In addition, signal molecules may adsorb to the exposed plant surface and accumulate there. Thus, the initially low concentrations will increase, in principle to any concentration.

As argued by Firm and Jones, the crucial question is how plants can distinguish signal from noise. For some reason, they take a ubiquitous compound, like ethylene, as an example. Generally, however, upon attack, several compounds are released that are not ubiquitous and occur in specific ratios⁴. Hence, there is every opportunity for plants to detect 'changes in the air'.

As an aside, although ethylene is occasionally suggested as a candidate substance for interplant communication⁵, we are not aware of any evidence. Many functions of ethylene are known, but virtually all take place within plants⁶. In fact, so many functions are known that it is hard to imagine how undamaged recipients should respond to such a ubiquitous signal in absence of modifying additional signals. Moreover, the 'generally accepted' threshold for physiological activity of ethylene is not necessarily the rule for other compounds.

We fully agree with Firm and Jones that the 'criterion of recipient detection', as they call it, is of paramount importance. In fact, it is hidden in our definition of interplant communication⁷; we proposed to reserve the term communication for those cases where physiological changes in recipient plants are demonstrated – hence, where signals are shown to be detected!

We think that there is compelling evidence for physiological changes in undamaged plants that receive damage-related volatiles⁷. Hence, plants can hear, but it is, as yet, unknown how good their ears are. Are they good enough for detection of signals under field conditions? Field evidence for plant–plant communication is needed, however difficult it may be to obtain. Not only because the effects may be small, but also because plant individuals can be expected to sometimes play deaf.

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The 'paradox' of polyembryony

Hardy¹ reports Gleeson *et al.*'s² population genetic models of polyembryony. Polyembryony can be found in a wide diversity of organisms, including armadillos³, cyclostome bryozoans⁴, starfish⁵, parasitic flatworms⁶ and hydrozoans^{7,8}, as well as parasitoid wasps⁹. The resultant embryos are genetically identical with the initial one, which generally develops from a sexually produced egg.

If the mother's genotype is relatively successful, and if the environment doesn't change rapidly, then parthenogenesis may be advantageous compared with sexual reproduction.