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How do the Plants Perceive Signals?

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SUMMARY

Volatile organic compounds are important mediators of mutualistic interactions between plants and their physical and biological surroundings. Volatiles rapidly indicate competition or potential threat before these can take place and they regulate and coordinate adaptation responses in neighbouring plants, fine-tuning them to match the exact stress encountered. Ecological specificity and context-dependency of plant–plant communication mediated by volatiles represent important factors that determine plant performance in specific environments.

INTRODUCTION

Plants communicate via the emission of volatile organic compounds (VOCs) with many animals as well as other plants. The plants may possess odorant-binding proteins (OBPs). OBPs transport VOCs to as-yet-undefined olfactory receptors (ORs) that activate the olfactory neurons, in turn responsible for the transduction of odorous stimuli into electrical signals that trigger in the receiving organism appropriate responses and choices leading to VOC perception (Ninkovic *et al*., 2021).

Plant VOCs may be emitted constitutively or may be induced by stresses. VOCs allow plants to communicate with other organisms and thus improve plant fitness (e.g., deterring herbivores, improving reproductive success) is true in the case of induced VOCs but may not apply to constitutive VOCs that are emitted lifelong. It may be argued that constitutive VOCs that are not induced by a stress or limited to a plant phenological stage represent a too-high metabolic and energetic cost for the plant, to be used only for communicating with other organisms (Karban *et al*., 2014).

VOC-driven interactions are considered as core modules of the ecological webs governing the behaviors of species and individuals, especially in a competitive/hostile environment. The capacity of some plants emitting VOCs to influence the metabolism and behavior of neighboring receiving plants has been noticed. The hormone ethylene (a VOC itself) can be perceived by plants through a receptor, it could be hypothesized that a receptor system must be present for all volatiles. It is clear that plants can respond to chemical signals including VOCs, the nature of the VOC-sensing system in plants is unclear.

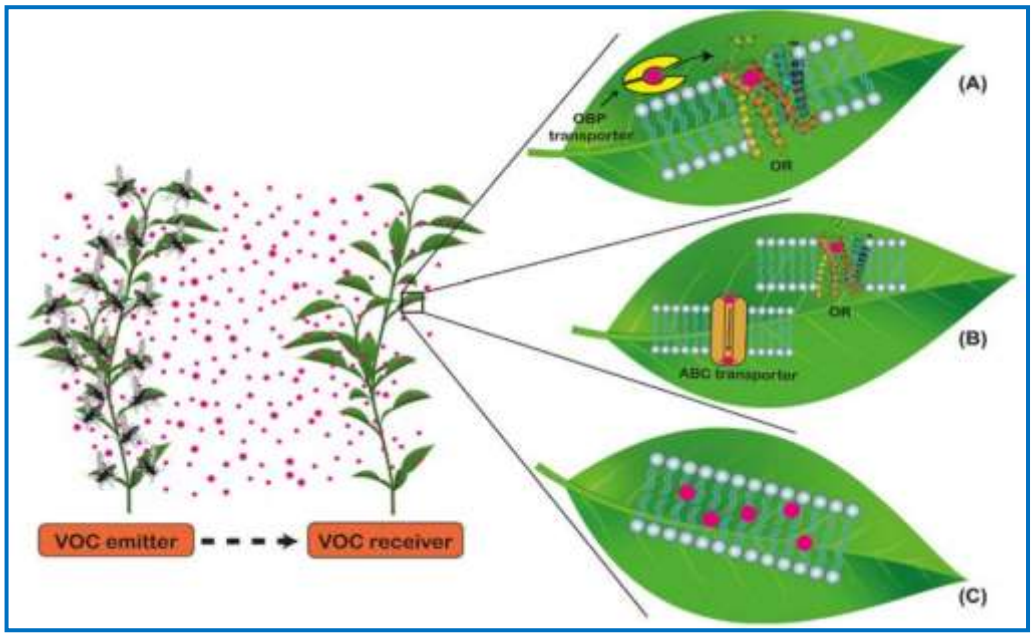

Fig. 1: Three different plant VOC reception machineries

Perception of VOCs by the plants:

The perception of VOCs by plants is an essential process by which plants interact with one another. Although the exact mechanisms are largely unknown, recent research has shed light on some possible mechanisms, including hormonal pathways, specific structures and specialised proteins. Three different hypotheses are discussed below and illustrated in Figure 1.

The plants possess more than one way of sensing exogenous VOCs, which ultimately effectively induce metabolic changes and reprogram gene synthesis and regulation. A first hypothesis is that plants possess a VOC-sensing system that is mediated by receptors. It is reasonable to think that, like in animals, proteins are used by plants as transporters that bring VOCs to receptors with some degree of specificity. A second possibility is that plants do not need OBP–OR systems to perceive VOCs.

Three cases may be envisioned.

(i) Plant OBPs act as bona fide ORs capable of triggering directly the cellular response. It is unclear how this may successfully deliver the signal to the transduction pathway and this possibility is not discussed further.

(ii) VOCs are directly bound to ORs that are embedded in membranes. The presence of ORs without OBPs transferring the volatile to them is unrepresented in higher organisms but has been reported in invertebrates, where ORs are directly connected to an embryonal neuronal system.

(iii) Plants use active transporters to facilitate the passage of VOCs across the plasma membrane. For example, the presence of an ABC protein involved in active transport of VOCs into plant cells has been described. This mechanism would represent a totally novel way of receiving and transferring VOC information in plants.

A third option is that plant sensing of VOCs is not mediated by protein transporters and receptors as in other organisms. When reaching a receiving plant, VOCs may act in a more direct way; for example, by changing the physical and chemical properties of cell membranes or by scavenging reactive oxygen species (ROS) that are formed in stressed leaves. There is solid experimental evidence in favor of these two mechanisms. Most VOCs are lipophilic, and by dissolving in cellular membranes they may change the membrane permeability to ions. Some cations, such as Ca^{2+} and K^{+}, are able to trigger changes of membrane potentials, in turn activating defensive metabolisms and physiological changes (Adebesin *et al*., 2017).

CONCLUSION

The plants possess more than one way of sensing exogenous VOCs, which ultimately effectively induce metabolic changes and reprogram gene synthesis and regulation. VOC perception is a crucial tool for a plant to adjust its growth strategy and improve its fitness. Understanding the complex regulation of genetic and metabolic pathways could provide an important tool for commercial and sustainable agriculture.

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