NEMATODE CONTROL

New allies to fight worms

Plant elicitor peptides (Peps) enhance immunity against diverse pathogens. Engineering a naturally occurring rhizobacterium to deliver Peps to the plant root system offers a new opportunity in integrated pest management.

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Plant-parasitic nematodes are among the world's most destructive plant pathogens, causing estimated annual losses of $8 billion to US growers and of nearly $78 billion worldwide[1]. Most current control methods rely on chemical nematicides, but their use is increasingly limited due to environmental concerns[2]. An alternative pest management strategy focuses on enhancing the host plant's immune system instead of directly targeting the pathogen. Plant elicitor peptides (Peps) are endogenous molecules that are released following cell damage or pathogenic attack and enhance plant immunity against a broad range of pathogens[3]. However, a suitable delivery system targeting root-dwelling pathogens is currently unavailable. In this issue of *Nature Plants*, Zhang and Gleason demonstrate the effective use of Peps to combat root-knot nematodes (RKNs) in potato (*Solanum tuberosum*) and present a unique root delivery system based on the rhizobacterium *Bacillus subtilis*[4].

The first evidence that Peps could be used to effectively manage nematode infections in plants emerged from a study of soybean (*Glycine max*). Exogenous treatment of seeds with GmPeps reduced the reproduction of the RKN *Meloidogyne incognita* and the cyst nematode *Heterodera glycines*[5]. Unlike soybean, potatoes are not grown from seeds but from small cubes of potato tubers, known as seed potatoes, that were grown in the previous season. To explore possible application of Peps in nematode management in potato, Zhang and Gleason analysed the GmPeps homologue StPep1. Watering potato plants with StPep1 solution prior to inoculation with the RKN *Meloidogyne chitwoodi* significantly reduced the RKN's infection rate. The number of galls and egg masses — typical indicators of successful RKN infection — significantly decreased following StPep1 treatment. However, direct treatment of *M. chitwoodi* juveniles with StPep1 did not reduce nematode viability. These results demonstrated that StPep1 can be used as a defence elicitor to enhance resistance to RKNs in potato[4].

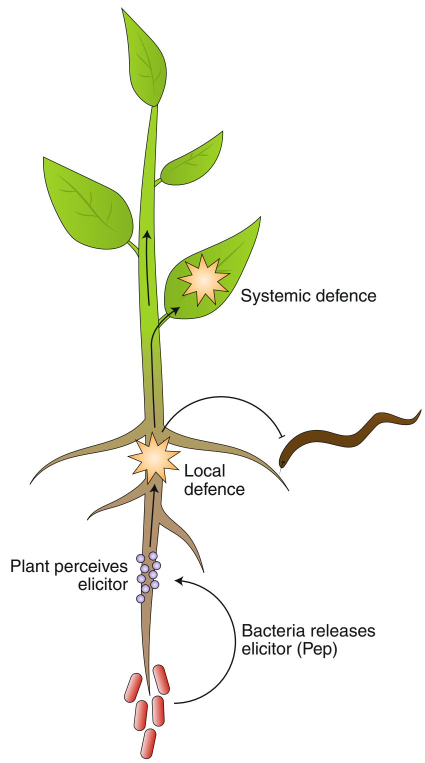

Fig. 1 | Pep delivery through *B. subtilis* enhances plant immunity against RKN. The engineered rhizobacterium *B. subtilis* secretes Peps, which are recognized through membrane-bound Pep receptors (PEPR) in the roots. Pep perception triggers local and systemic responses that correspond with an enhanced resistance against RKN.

B. subtilis is a naturally occurring plant growth-promoting rhizobacterium that is classified as 'generally recognized as safe' by the US Food and Drug Administration. Previously, Warnock and colleagues used *B. subtilis* to secrete nematode neuropeptides into the rhizosphere of the tomato (*Solanum lycopersicum*) root system and successfully targeted nematodes to reduce their infection rate[6]. Zhang and Gleason were able to engineer *B. subtilis* in a similar fashion to express and secrete StPep1. By treating potato plants with StPep1-secreting *B. subtilis*, the authors were able to replicate the enhanced resistance to *M. chitwoodi*[4].

The authors used a global transcriptomic approach to investigate the root response of potato to StPep1 treatment. They identified 765 genes that were differentially expressed after treatment with StPep1 solution. Seven StPep1-responsive genes that were differentially expressed were chosen as marker genes. Five of these marker genes were also upregulated in roots following treatment with StPep1-secreting *B. subtilis*. Thus, treating potato with StPep1-secreting *B. subtilis* triggers changes in gene expression in roots similar to those elicited by StPep1 solution, and this defence response is associated with enhanced resistance to *M. chitwoodi*[4].

Besides chemical nematicides, methods of nematode management include the use of crop rotation, microbial biocontrol agents, cover crops, trap crops, soil solarization, fumigation and resistant plant varieties. However, several of these strategies are not effective or available for all crops. Nematicides are highly toxic, and their use is strictly limited due to environmental concerns. Resistant plants are often ineffective or unavailable. Microbial biocontrol agents have produced inconsistent results. In this context, the current work provides a new opportunity to manage plant-parasitic nematodes by combining two progressive strategies: the use of plant elicitors to enhance crop resistance to pathogens and the use of *B. subtilis* to deliver these elicitors efficiently (Fig. 1).

Traditional pest control substances used to expel or eliminate pathogens are highly toxic and have negative effects on the ecosystem that cannot be avoided. By contrast, Peps are naturally occurring in plants and are therefore endogenous to the agricultural system. While Pep elicitors are widely distributed in angiosperms, perception is limited to related species[7], reducing the risk of undesirable effects on non-targeted plants. Strong defence reactions in plants are often associated with growth impairment, which would be detrimental in cropping systems. Zhang and Gleason ruled out this possibility: StPep1 treatment did not alter the shoot or root biomass of potato[4].

Although using a microbial vector to deliver molecules is a relatively new concept in crop protection, microbial drug delivery has been used in medical research. While promising results have been achieved in mice, a major challenge in successfully applying this approach in humans is the absence of an efficient system for delivering the proper dosage of a molecule based on the longevity and self-renewal of the bacteria[8]. For plant protection, *B. subtilis*, on the other hand, appears to offer a continuous supply of the required plant elicitor when employed in its natural habitat. Indeed, Zhang and Gleason showed that StPep1-secreting *B. subtilis* continued to associate with the potato root for up to 12 days after inoculation[4]. This unique delivery system could thus easily be engineered to secrete a variety of molecules, allowing for diverse applications and rapid deployment[9]. ❐

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Published online: 08 June 2020
https://doi.org/10.1038/s41477-020-0699-y

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Author contributions

C.H. drafted the initial version of the manuscript. S.S. finalized the manuscript and designed the figure.

Competing interests

The authors declare no competing interests.