frontiers | Frontiers in Science

TYPE Frontiers in Science Editorial
PUBLISHED 15 October 2024
DOI 10.3389/fsci.2024.1483167

Check for updates

OPEN ACCESS

EDITED BY
Frontiers in Science Editorial Office,
Frontiers Media SA, Switzerland

*CORRESPONDENCE
Nicole M. van Dam
vandam@igzev.de

RECEIVED 19 August 2024
ACCEPTED 04 September 2024
PUBLISHED 15 October 2024

CITATION
van Dam NM. Mobilizing induced resistance for sustainable crop production. *Front Sci* (2024) 2:1483167. doi: 10.3389/fsci.2024.1483167

Mobilizing induced resistance for sustainable crop production

Nicole M. van Dam[1,2]*

[1]Leibniz Institute of Vegetable and Ornamental Crops (IGZ), Großbeeren, Germany, [2]Institute of Biodiversity, Friedrich Schiller University Jena, Jena, Germany

KEYWORDS

induced plant defense, pesticide reduction, sustainability, agrifood systems, biostimulants, crop production, healthy plants

An Editorial on the Frontiers in Science Lead Article
Enabling sustainable crop protection with induced resistance in plants

Key points

- Scientific evidence suggests that induced resistance (IR) in plants can be successfully implemented for sustainable crop production through integrated pest management strategies.
- Governments need to create a legal framework for implementing novel, science-based approaches to promote the implementation of IR stimulants.
- Scientists, breeding companies, and farmers should collaborate more closely to ensure that the implementation of IR will be effective and economically viable.

Born in the 1960s, I grew up with the book *Silent Spring* (1). In this book, Rachel Carson reports on the environmental problems caused by synthetic pesticides, in particular dichlorodiphenyltrichloroethane, better known as DDT. This highly effective pesticide did not only kill insect pests and mosquitos but also insectivorous birds and their predators, birds of prey, due to the accumulation of toxic DDT in the food chain. This strongly motivated me to study plant biology and pursue a scientific career studying natural plant defenses. After all, insect herbivores and pathogens present serious threats to crop production, linking directly to feeding a growing world population. Over millions of years, plants have evolved strategies to survive pathogens and herbivores as large as dinosaurs. If we "learn from nature," therefore, we can develop smarter crop protection strategies that protect plants without harming ourselves or our environment.

Induced resistance (IR) is one of the smart strategies that plants have up their sleeve. As elucidated in the insightful lead article by Flors et al. (2) in *Frontiers in Science*, plants possess a wide array of natural resistance mechanisms that help them to survive herbivore and pathogen attacks. These include constitutive defenses, which are produced continuously (i.e., waxy epidermal cuticles, bark, cell walls, etc.). Plant resistance can also be upregulated when there is an actual attack. The latter strategy, which includes IR, is considered a cost-saving strategy because the plant only invests in producing defenses when needed and the saved resources can be allocated to growth and reproduction instead (3).

Over the last four decades, a large body of scientific research has also shown that IR can be specifically targeted at the attacker. Based on specific cues, called pathogen- or herbivore-associated molecular patterns, or PAMPs and HAMPs, respectively, plants can recognize their attackers (4). They deploy certain defense responses to reduce damage caused by the particular herbivore or pathogen that is attacking, again optimizing the allocation of resources to resistance production most efficiently. In contrast to constitutive defenses, IR reduces the pressure on pathogens and herbivores to evolve mechanisms to detoxify or circumvent their host's defenses. The specificity of the IR response may also avoid non-target effects on beneficial organisms, such as pollinators (5), or toxicity to humans. In fact, Flors et al. note that the increased production of certain defensive metabolites may enhance the health aspects of our crops. Glucosinolates—typical compounds found in cabbage and mustard—are a well-known example. They lend resistance to herbivores and pathogens as well as provide health benefits for humans because glucosinolates have anti-inflammatory, antioxidant, and anti-carcinogenic effects (6). Thus, when IR causes a glucosinolate increase, crops like cabbage and mustard become even more nutritious for us.

In addition to these plant intrinsic IR mechanisms, beneficial microbes associated with plants can also promote IR. Bacterial and fungal mutualists may either elicit broad-spectrum IR via induced systemic resistance (ISR) or systemic acquired resistance (SAR) or by priming the plant for future attacks (2). Priming is particularly interesting as it boosts the response to attackers (mostly without involving the costly production of resistance) before they arrive (7). An additional advantage of applying beneficial microbes, particularly those associated with plant roots, is that they commonly promote plant growth by enhancing nutrient and water uptake. Taken together, the benefits of IR make it indeed worthwhile to explore its application in sustainable crop production.

Yet, despite the obvious advantages and the urgent need for sustainable alternatives to synthetic pesticides, Flors et al. (2) observe that IR is rarely deployed in agricultural production systems. This is a missed opportunity, especially regarding our accumulated knowledge of the molecular and physiological mechanisms underpinning IR. Synthetically produced HAMPs or PAMPs that trigger IR responses could be applied as a spray to protect crops, for example. Similarly, breeders could use the knowledge generated to select for crop varieties with more effective IR responses. It has also been found that certain maize varieties possess genes coding for herbivore-induced volatiles. When attacked by herbivores, plants emit these volatiles which act as a "cry for help" to attract natural enemies that either parasitize or prey on the herbivores (8). Such maize varieties could be more suitable for integrated pest management (IPM) systems in which natural enemies are augmented as one of the sustainable strategies to reduce crop damage. The authors also mention that we could implement our knowledge of the epigenetic regulation of IR. This would imply that—either via novel gene editing techniques or epigenetic imprinting of the seeds—IR to pests and pathogens could be sped up or boosted. This is a very exciting prospect, though it is currently not yet ready for immediate application. In other words, there is sufficient knowledge and potential to integrate IR into IPM systems. Why, then, has it barely been implemented?

Flors et al. specify various factors limiting the application of IR in agriculture. The application of HAMPs, PAMPs, or phytohormones to stimulate IR might come with a growth penalty and thus a loss of productivity, for example. However, this could also be the case for the use of synthetic pesticides. The potentially negative effects of IR could further be mitigated by optimizing the dosage, timing, and environmental conditions of IR stimulant application. This would, of course, require investment in well-designed manipulative field studies on a near-production scale. Scientists, crop breeders, farmers, and consumers need to also collaborate more closely to make the application of IR transferable. It would ensure that science-based solutions are economically viable and provide sustainable incomes for farmers and farm workers. Moreover, any solutions must be acceptable to consumers. For example, stimulating cabbage to produce more glucosinolates does not only render them more resistant and healthier but also changes the flavor and thereby affects consumer acceptance. Innovative co-working and experimental formats, such as co-creation and living labs, may serve as ideal platforms to test the implementation of IR and other forms of natural resistance as well as ensuring that solutions are taken onboard by consumers. Another hurdle for implementation is the legal framework for introducing novel IR-inducing biostimulants to the (European) market. The safety and effectiveness of novel products must be sufficiently assessed, of course. However, the administrative demands are often such that only very large enterprises can provide the necessary documentation for market admission. This inhibits the innovative power of scientific institutions and small and medium-sized enterprises.

In conclusion, there is sufficient knowledge and potential to integrate IR approaches into agricultural practices toward sustainable crop production. However, it certainly is not a "golden bullet" that can protect our crops from any harm. This means we should stop treating our agrifood production systems as predictable "food factories." Instead, we should manage them for what they are: complex agroecosystems in which many organisms interact. IR is an intrinsic part of these interactions; when managed well, it can reduce pest damage and support sustainable food production.

Statements

Author contributions

ND: Conceptualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The author received funding from Leibniz IGZ, as well as DFG (German Research Foundation) and BMBF (Federal Ministry of Education and Research) for various research projects. Neither of these funders were involved in the writing of this article or the decision to submit it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author declared a current collaboration with the lead article author, MJP.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Carson R. *Silent spring (First Mariner Books edition 2002)*. Boston, MA: Houghton Mifflin Company (1962). Available at: https://www.fao.org/fileadmin/templates/library/pdf/Silent_spring.pdf

2. Flors V, Kyndt T, Mauch-Mani B, Pozo MJ, Ryu C-M, Ton J. Enabling sustainable crop protection with induced resistance in plants. *Front Sci* (2024) 2:1407410. doi: 10.3389/fsci.2024.1407410

3. Karban R, Myers JH. Induced plant responses to herbivory. *Annu Rev Ecol Syst* (1989) 20(1):331–48. doi: 10.1146/annurev.es.20.110189.001555

4. Martinez-Medina A, Flors V, Heil M, Mauch-Mani B, Pieterse CMJ, Pozo MJ, et al. Recognizing plant defense priming. *Trends Plant Sci* (2016) 21(10):818–22. doi: 10.1016/j.tplants.2016.07.009

5. Mithöfer A, Boland W. Recognition of herbivory-associated molecular patterns. *Plant Physiol* (2008) 146(3):825–31. doi: 10.1104/pp.107.113118

6. Qin H, King GJ, Borpatragohain P, Zou J. Developing multifunctional crops by engineering Brassicaceae glucosinolate pathways. *Plant Commun* (2023) 4(4):100565. doi: 10.1016/j.xplc.2023.100565

7. Strauss SY, Rudgers JA, Lau JA, Irwin RE. Direct and ecological costs of resistance to herbivory. *Trends Ecol Evol* (2002) 17(6):278–85. doi: 10.1016/S0169-5347(02)02483-7

8. Turlings TCJ, Erb M. Tritrophic interactions mediated by herbivore-induced plant volatiles: mechanisms, ecological relevance, and application potential. *Annu Rev Entomol* (2018) 63:433–52. doi: 10.1146/annurev-ento-020117-043507