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Systemic Activated Resistance –a New Dimension in Plant Protection

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Abstract

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Fungal pathogens are predominantly controlled by fungicides. In the concept of Systemic Activated Resistance (SAR) pathogens are not directly affected, but indirectly by a mobilization of plant resources, expressed by a cascade of multiple defense reactions. After a brief historical introduction, the underlying principles of SAR are characterized and its efficacy is demonstrated. Advantages and information deficits of this concept are briefly discussed, with an outlook on the future development of this new dimension in plant protection for sustainable agriculture.

Introduction

Inducible resistance in plants against pathogens has attracted and deserves special attention. This phenomenon is defined as follows. After treatment with microorganisms or chemical substances, plant parts of hitherto susceptible cultivars become resistant. There are several types of inducible resistance (4, 6, 8). This presentation will focus on only one type, the Systemic Activated Resistance (SAR).

Definition

SAR is characterized by the following principle (Fig.1)

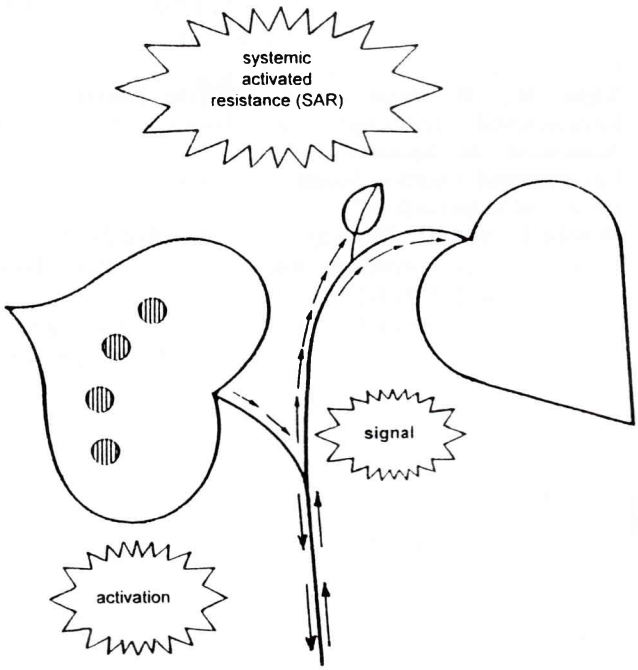

Figure 1. Development of Systemic Activated Resistance (SAR) (5).

Upon irritation of a plant tissue by microorganisms or chemicals, a signal of yet unknown nature is released. This and/or a second signal is then translocated to untreated tissues or plant parts. There it conditions and intensifies a resistance response, when these parts are challenged by inoculation with plant pathogens.

Two classical examples will demonstrate the principle. The first concerns a protection of tobacco leaf tissue with *tobacco mosaic tobamovirus* (TMV) against TMV (Fig. 2).

The second example deals with a protection of cucumber leaves with the leaf-spotting fungus *Colletotrichum lagenarium* (Table 1).

Inoculation of the first true leaf protected the second and third leaves against the same fungus under field conditions.

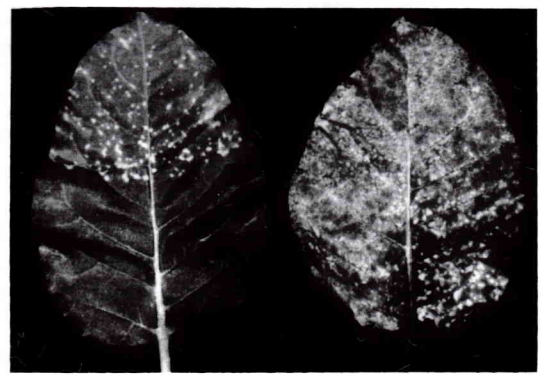

Figure 2. Leaves of tobacco cv. Samsun NN inoculated with TMV on the upper part (left) and unicolutated (right), both inoculated with TMV seven days later. The lower part of the left leaf exhibiting complete resistance against the challenge inoculation (7).

Characterization

SAR is characterized by the following parameters:

- It results from an activition of plant defenses and not from a direct control of pathogens.
- There is no dose-effect response.
- It needs an activation period of 2-7 days.
- It is expressed also in plant cultivars with no resistance genes for a particular plant pathogen.

- Biotrophic obligate as well as non-obligate pathogens are affected.
- It is expressed against all pathovars or pathotypes of a pathogen.
- It is apparently polygenic and must therefore be regarded as horizontal resistance and thus durable.
- Its expression is only temporarily, therefore the low selection pressure will not enforce a selection of resistance over-coming pathogens.

In principle, SAR operates by mobilization of plant resources in self-defense.

Table 1. Protection of Wisconsin SMR 58 cucumber leaves against *Colletotrichum lagenarium* by *Colletotrichum lagenarium* under field conditions (1)

Chall-enged leaf	Mean number of lesions/ leaf [a]		Mean diameter of lesions (mm^2)[a]		Area of lesions per leaf (mm^2 [a]	
	UP/C	P/C	UP/C	P/C	UP/C	P/C
2	36.1	7.2***	4.1	1.4***	485.9	11.6***
3	10.9	3.6***	3.5	0.4***	108.5	0.5***

UP/C = leaf 1 unprotected, leaves 2+3 challenged
P/C = leaf 1 protected, leaves 2+3 challenged
[a] = recorded 8 days after challenge
*** = Significant at the 0.001 P level

Specificity

SAR is relatively unspecific as far as activators and plant responses are concerned. It is triggered by plant pathogenic viruses, bacteria and fungi as well as by abiotic and biogenic chemicals. Viruses can activate a defense against fungi, bacteria can trigger a synthesis of phytoalexins, which are of no use against their attack. It appears, that all possible defense systems are activated, irrespective of the kind of activator.

Mode of action

The mechanisms underlying the expression of SAR are not yet fully understood. The operational flow can be characterized in a simplified version by the following steps:

- Complex interactions on and in the plasmalemma of an irritated plant cell results in a formation of one or more signal substances.
- These signals are translocated within a cell, to adjacent cells or to tissues of other non-challenged plant parts.
- Affected plant tissues respond with a cascade of multiple defense reactions, which are unspecific and undirected with regard to the kind of activator.
- In cells which have received the signal(s) prior to pathogen attack, there are intensified resistance responses when they are challenged by inoculation. These include an accumulation of antimycotic phytoalexins, pathogenesis-related (PR)-proteins and lignin as well as a more pronounced papillae formation against haustoria of biotrophic fungal pathogens.

As research on SAR is conducted worldwide, open questions with regard to the mode of action are expected to be answered in the near future.

Development

The concept of SAR, formerly called aquired physiological immunity, is about 100 years old. Since a review in 1933 (2) numerous papers have been published, mostly dealing with academic investigations and rarely with field trials. There was, however, no way of a large-scale practical application on the horizon. Meanwhile, the chemical industry has screened a large number of compounds for their potential as inducers of SAR (9). In 1995 CGA 245704 (BION) was presented as inducer of SAR for commercial plant production and protection (5).

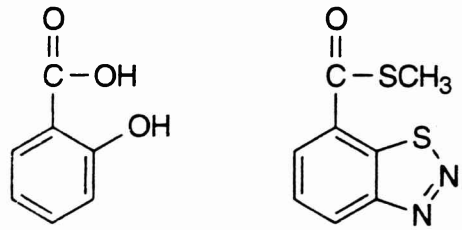

Figure 3. Chemical structures of salicylic acid (left) and BION (right).

The benzothiadiazole derivative (Fig. 3) fulfills all requirements for an inducer of SAR and has been found to increase resistance against a range of plant pathogenic fungi as well as bacteria:

Oomycota (*Pseudoperonospora, Phytophthora, Bremia*)
Ascomycota (*Blumeria, Erysiphe, Cochliobolus, Magnaporthe, Mycosphaerella, Sclerotinia*)
Basidiomycota (*Corticium, Puccinia*)
Mitosporic fungi (*Alternaria, Colletotrichum*)
Bacteria (*Pseudomonas, Xanthomonas*)

With a number of experiments the acro- and basipetally translocated BION has been found to mimick an induction of SAR by plant pathogens. Thus, its application induces nothing else but a natural phenomenon of self-defense in plants. Nature created the concept!

Mode of action of BION

For an expression of SAR, the interactions at the plasmalemma are of paramount importance. In compatible systems, the pathogen has means to successfully suppress the SAR. In incompatible systems the pathogen can not uphold the SAR and will be therefore contained. It has been proved with salicylic acid-deficient mutants of tobacco and *Arabidopsis thaliana* that BION can replace SA (Fig. 3), one of the identified signal substances. Its application offers the possibility to induce SAR also in compatible systems, where the pathogens would otherwise suppress its induction.

Efficacy

From the many trials with BION only three aspects will be cited. One application of 30g a.i./ha at GS 25-29 protected wheat plants sufficiently for about 60-70 days against the powdery mildew *Blumeria (Erysiphe) graminis* f. sp. *tritici*.

This effect is due to an inhibition of haustorial development (Fig. 4) by increased papillae formation and hypersensitivity response. Application to seed boxes of rice protected the plants after transplantation into the field completely for about 70 days against *Magnaporthe* (ana. *Piricularia*) *grisea*, the causal agent of rice blast. Glasshouse experiments have shown (D. Falconi and E. Schlosser, unpublished) that seed treatments as well as foliar applications gave a complete protection of chickpeas, french beans and lentils against soilborne *Corticium rolfsii*. Thus, there is a chance that at least some pathogens attacking underground parts of plants might be successfully controlled by foliar applications, which would fulfill a dream of plant pathologists. Though these results are impressive, they do not imply that BION is sufficiently effective against all plant pathogens.

Outlook

Despite the promising perspectives, it must not be overlooked that there is a number of open questions with regard to the BION mediated efficacy of SAR:

- Which pathogens are affected and to what extent?
- What are the optimum concentrations for various systems and which dosages are phytotoxic?
- Which GS of plants is best for application to obtain a long lasting protection?
- What is the role of plant genotypes in the degree of resistance expression?
- Do ontogenetic stages of plant parts differ in their response?
- What impact do various factors, e.g. climatic conditions, water stress or logging and nutritional status of plants have on the degree of resistance expression?

Despite this critical annotations, a practical utilization of SAR will lead into a new dimension of plant protection in sustainable agriculture. Besides, this new technology offers a welcome alternative to transgenic plants as SAR is effective against a variety of plant pathogens, and most importantly, all their pathotypes. Such a broad spectrum control can never be achieved with transgenic plants.

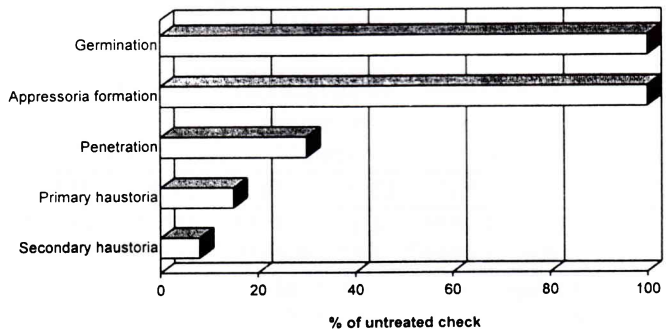

Figure 4. Development of *Blumeria graminis (Erysiphe)* f. sp. *tritici* on wheat leaves after treatment with BION in comparison to the untreated check (3).

الملخص

شلوسر، ايكارت. 1997. المقاومة الجهازية المحرضة: بُعد جديد في وقاية النبات. مجلة وقاية النبات العربية. 15(2): 147-149.

تتم مكافحة ممرضات النبات، على نحو رئيسي، بوساطة الكيماويات. أما في مفهوم المقاومة الجهازية الممرضة، فإن الممرضات لاتتأثر بشكل مباشر، ويتم احتواؤها من خلال مستوى دفاعي مرتفع في النباتات المصابة. ويتم تحريض هذه المقاومة الجهازية بوساطة مؤثرات لاعضوية أو مؤثرات حيوية المنشأ، إضافة للممرضات، ويعبر عنها في النباتات في غياب مورثات مقاومة ضد الممرض المعني، وتكون فعالة ضد كافة الأنماط المرضية للكائنات المسببة؛ ويحتاج تفعيلها من 2-7 أيام. وبعد مقدمة للتطور التاريخي لمفهوم هذا النوع من المقاومة، سيتم تعريف مبادئها الرئيسية، كما سيتم عرض فعاليتها بنتائج من تجارب حقلية. وسيناقش الباحث محاسن الطريقة ومحدوديتها مع نظرة على التطور المستقبلي لهذا البعد الجديد في وقاية النبات من أجل زراعة مستدامة.

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