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Defense reactions of Hevea brasiliensis to root rot diseases

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Abstract

Some reactions differentiated by rubber trees to root rot diseases are described at molecular, cellular and histological levels.

1 Introduction

Hevea brasiliensis plantations, grown in humid tropical climates for rubber production, are ravaged by *Rigidoporus lignosus* and *Phellinus noxius*, two basidiomycetes responsible for white rot in the Ivory Coast (Nandris et al. 1981, 1983 b). The loss of the decayed root system is often compensated by a new tap root differentiation (Nicole et al. 1981, 1983). This loss results primarily from the degradation of cell structures (Nicole et al. 1982 a, b; Geiger et al. 1983 a) caused by fungal enzymes excreted into the host tissues (Geiger et al. 1976, 1983 b, 1984; Geiger and Huguenin 1981).

This publication presents some typical host reactions elaborated for defense, from penetration up to an advanced stage of the disease.

2 Materials and methods

All materials and methods were previously described by Geiger (1975), Geiger et al. (1976, 1984), Nicole et al. (1982 a, b) and Nandris et al. (1983 a).

3 Results

Numerous reactions elaborated by rubber trees have been characterized at all the stages of the infectious process of each parasite.

Early reactions. They occur at the initial stages of penetration. The most characteristic of these reactions is a hypertrophy and hyperplasia of young differentiated cells of the phellogen. This mechanism is often initiated around one or two necrotic cells, raising the possibility of hypersensitivity.

Post-initial reactions. These reactions are elaborated during the penetration and invasion of the first cell layers. The most consistently occurring of these reactions in *Hevea* is most certainly the increase of cell layers under the points of penetration. It results from a stimulation of the activity of the cork cambium. The walls of certain cells thicken concomitantly. The identification of the nature of this thickening shows that it was composed of suberin or lignin.

Reactions occurring during the colonization of tissues. All tissues, whether or not they are lignified, are involved by these reactions. In the young cork, for example, some cell walls are deformed, taking on a notched appearance. Microscopic observation has revealed wall appositions in the periplasmic space of the cells. When examined under ultraviolet light, these deposits fluoresce and are thus probably composed of callose. Similarly in the phloem, clumps of callose obstruct the pores of sieve tubes.

In the region of the xylem, the lignification process becomes heterogeneous. Cell islets are differentiated before the cambium in the young phloem probably in order to slow down the progression of invading hyphae. This is also the role of the tyloses which obstruct the water bearing vessels of the wood.

At the biochemical level, there is a considerable change in the spectrum of isoperoxidases which can be extracted from different types of tissues. Healthy tissues are characterized by the presence of numerous isoenzymes, while reacting tissues and especially parasitized tissues from adult tap roots are characterized by the presence of one major isoenzyme. In the most typical cases, its activity accounts for almost 100% of total peroxidase activity and corresponds to the stimulation of the homologous isoenzyme of healthy tissues by a factor of 100.

This enzyme polymerizes coniferyl and p-coumarilic alcohols into insoluble products (DHP = dehydrogenative polymerisates) whose chemical structure is analogous to that of lignin. It is thus possible that this peroxidase contributes to an abnormally elevated lignification of certain tissues, leading to the construction of a barrier, whose purpose is to prevent the intertissue progression of the fungus. This type of wall thickening has in fact been observed.

The lignin contents in different tissues studied would tend to confirm this hypothesis. Healthy tissues close to the front of *R. lignosus* progression and above all the infected tissues taken from this front of progression have an abnormally high lignin content. It may be supposed that parasite invasion causes the host to react by lignifying. This reaction is, however, ineffective, since these tissues are subsequently degraded.

Late reactions. The anatomical organization of the *Hevea* tap root is occasionally disorganized by the differentiation of new tissues. We can thus distinguish:

- meristematic-like tissues initiated from the parenchymatous rays of the xylem. The organization of the cell foci is reminiscent of that of a meristem;
- phloem and ligneous tissues set in place by a neocambium. Native diseased tissues are rejected towards the exterior or are isolated from the rest of the root. In greenhouse conditions, 10% of the plants infected with *R. lignosus* exhibit this phenomenon. It is probable that it is identical to the mechanism initiating healing callus formation in adult trees naturally infected.

4 Discussion and conclusion

The global efficacy of all these reactions does not enable Hevea (GT1 clone) to resist attack by *R. lignosus* or *P. noxius*. When considered individually, however, certain of these reactions prevent the spread of hyphae in the tissues, which is the case for the cellular hypertrophy and hyperplasia and the supernumerary cortical cell layers under the points of penetration. Other reactions, on the other hand, are apparently much less effective, e. g. lignification and suberin synthesis of walls or callose deposits (wall apposition). Each of the parasites possesses enzymes which can degrade them.

On the other hand, tissue neogenesis eliminates diseased tissues. No contamination of new root structures has been observed after this process. This mechanism assures the survival of the plant, which assumes normal growth.

The comparison of these defense mechanisms with the CODIT (Compartmentalization of Decay in Trees) model (SHIGO and MARX 1977) shows, that the process of tissue neogenesis is equivalent to wall 4 of this model. The purpose of this barrier is to prevent the spread of decay to differentiated tissues after the parasitic attack. Finally, the compartmentalization mechanism of wood rots, already described in the case of other ligneous plants parasitized by other wood rot agents, is also applicable to the host-parasite couple *H. brasiliensis* / *R. lignosus* and *P. noxius*.

Summary

Some reactions of *Hevea brasiliensis* against root rot diseases caused by the fungi *Rigidoporus lignosus* and *Phellinus noxius*, are described at molecular, cellular and histochemical levels. It has been shown that rubber trees differentiate defense reactions during all stages of the infection. Cellular hypertrophy and hyperplasia, cambium activity stimulation and lignification and suberification of certain walls occur in the course of root penetration. Wall appositions, callose depositions, tyloses formation are some reactions observed during tissues colonization. Elaboration of meristematic tissues and induction of a new vascular cambium constitute late reactions.

Biochemical studies have revealed the increase of an isoperoxidase activity in both infected and reaction tissues. This isoenzyme is synthesized by the host and can be detected as early as penetration.

These reactions rarely enable rubber trees to resist the fungal attack.

Résumé

Réactions de défense de l'Hévéa aux agents de pourridié

Certaines réactions d'*Hevea brasiliensis* aux pourritures racinaires, causées par les champignons *Rigidoporus lignosus* et *Phellinus noxius*, sont décrites aux niveaux moléculaire, cellulaire, et histologique.

L'hypertrophie et l'hyperplasie cellulaires, la stimulation du cambium subéro-phellodermique, la lignification et la subérification des parois ont été observées au cours de la pénétration des hyphes dans la racine. Les dépôts de callose et la formation de tyloses constituent quelques réactions qu'oppose l'Hévéa à la colonisation des tissus par les parasites. Enfin l'élaboration de tissus à caractère méristématique ainsi que l'initiation d'un néocambium libéro-ligneux sont des réactions tardives, peu fréquentes.

Les études biochimiques ont révélé la très forte augmentation de l'activité d'une isoperoxydase tant dans les tissus infectés que dans les tissus réactionnels. Cette isoenzyme est induite par l'hôte dès la pénétration de la racine.

L'ensemble de ces réactions n'autorise que rarement une résistance des arbres aux attaques fongiques.

Zusammenfassung

Abwehrreaktionen von Hevea brasiliensis gegenüber Wurzelfäuleerregern

Einige Reaktionen von *Hevea brasiliensis* gegenüber den Wurzelfäuleerregern *Rigidoporus lignosus* und *Phellinus noxius* auf molekularer, zellulärer und histologischer Ebene werden beschrieben. Gummibäume zeigen Abwehrmechanismen in allen Phasen der Infektion. Zellhypertrophie, Anregung der Kambiumaktivität und Lignifizierung und Suberinisierung bestimmter Zellwände treten im Laufe der Wurzelinfektion auf. Zellwandverdickungen, Calloseablagerungen und Thyllenbildung sind einige Reaktionen, die während der Besiedlung des Gewebes beobachtet werden können. Die Ausbildung von meristematischem Gewebe und neuen Leitbündelkambien stellen seltener beobachtete Spätreaktionen dar.

Biochemische Untersuchungen ergaben die Zunahme einer Isoperoxidaseaktivität in infiziertem Gewebe und im Reaktionsgewebe. Dieses Isoenzym wird vom Wirt gebildet und tritt schon mit dem Eindringen des Pathogens auf.

All diese Reaktionen ermöglichen es Gummibäumen allerdings nur selten, Angriffen von Pilzen zu widerstehen.

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