Many Tendrils and Vines Use Adhesives in Lieu of or in Addition to Twining or Coiling

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Abstract

Previous work in our laboratory has shown that the coiling of tendrils and vines is controlled in large part by the production of gelatinous fibers. However, in many cases this is not the sole mechanism for the adherence of tendrils or vines to their support structures. In addition, many tendrils produce an adhesive that aids in the adherence of the tendril or vine or in some cases is used as the sole mechanism for adhesion. In Virginia Creeper, for example, the tendrils possess limited ability to coil, but produce large quantities of adhesive at the ends of papillate cells. This adhesive is reactive with monoclonal antibodies that recognize pectinaceous mucilages, arabinogalactan proteins, and callose. The adhesive appears to be highly heterogeneous with pockets of reaction for several components, and rafts of a composite consisting of pectinaceous components surrounded by a callosic core at the contact surface/papillate cell interface. Additional, more mobile components, composed of arabinogalactans and mucilaginous pectins, intercalate the support and ascend back through the proximal ends of the papillate cells. The walls of the papillate cells are devoid of all of these same wall components, indicating that the source of at least some of the adhesive is from the re-mobilization of polysaccharides from the papillate cell walls. Although Virginia Creeper tendrils do not coil, the strong ability to stick onto other objects allows them to ascend entities, such as flat objects, that other tendril-climbers or twiners could not. These data indicate that vines may utilize adhesives in addition to or in lieu of the normal coiling or twining habit to ascend objects of unusual morphology.

Introduction

Previously, we have documented the mechanism by which tendrils of vining plants are able to coil (Meloche et al., 2006). However, not all tendrils use coiling as a mechanism to attach to a support. In addition to (or in lieu of) the coiling process, some plants produce an adhesive pad. Virginia Creeper is one species that utilizes adhesive pads, allowing the Virginia Creeper to ascend flat-faced or large-diameter objects with ease, with adhesive pads their only support. Unfortunately, little is known of the nature of the adhesive or the manner in which it is produced. In this report, we describe structural and immunocytochemical studies that allow us to document the composition of this very effective adhesive.

Material and Methods

In order to capture adhesive tendrils of Virginia Creeper, we fastened sheets of nitrocellulose to the walls of structures just above where Virginia Creeper was actively growing. The Virginia Creeper then produced adhesive pads that were stuck to the nitrocellulose rather than the wall, allowing their non-destructive removal for microscopy. Both mature and immature tendrils with adhesive pads were observed. Protocols for microscopy, immunogold, and immunogold-silver were as described in Meloche et al. (2007). *Planta* 225: 485-498.

Results and Discussion

At the terminal ends of Virginia Creeper tendrils are adhesive pads that allow it to attach to many objects. These tendrils start out as isobilateral organs (Fig 1A), but after contact stimulation, some of the epidermal cells elongate exceptionally and become papillate cells that will contact the substrate (Fig 1B as an early stage, 1 C at maturity). Along the interface of the nitrocellulose and the adhesive pad, areas of highly-stained extracellular deposits may be identified that are the adhesive (Fig 1C & D). Within the tendril, gelatinous fibers occur as a cluster in the center of the organ (Fig 1C). At the electron microscopic level, a raft of adhesive and a melange of wall components occurs at the base of the cells (Fig 2A), that may be involved with both attachment or in buffering the cells from the contact with the surface to which they adhere. Oddly, the side walls of the papillate cells are highly pitted (Fig 2B), indicating that components have been lost from these walls.

To characterize the adhesive and other cells in the Virginia Creeper tendril, a battery of antibodies to wall components and mucilages were used to probe sections at the light and electron microscopic level. The most striking changes occur with the antibodies that recognize pectinaceous or mucilaginous epitopes (Fig 3). Antibodies that recognize the galactan and arabinan sidechains of RG-1 (LM5 and LM6, respectively) label cells of the tendril with the exception of the papillate cells. However, antibodies that recognize pectin mucilages such as M34, M36, and M38 strongly label not only the cell walls of the papillate cells, but also areas within the adhesive, although all seemed to label different compartments/areas within these cells and adhesive. Similarly, antibodies raised to RG-1 (M2, M22) labeled both the cell walls and areas of the adhesive. Antibodies that recognize arabinogalactan proteins (AGP's) such as JIM 8 & 13 were also enriched in the adhesive zone.

At the electron microscopic level, this heterogeneity of the adhesive material is more obvious. AGP's are found throughout the raft material, into the pores of the nitrocellulose, indicating it has been extensively re-mobilized from the existing walls into the adhesive. Within the rafts of material deposited at the nitrocellulose/papillate cell interface, bands of material reactive with callose (Fig 4B), arabinogalactan protein (Fig 4A), and various of the pectinaceous mucilages are obvious (not shown). Some of the pectinaceous mucilages also label material away from the rafts and in the spaces around the nitrocellulose. The pitted appearance of the papillate cell walls and their lack of immunolabeling indicate that wall components from these cells were remobilized to form the adhesive. Because antibodies to RG-1 side chains are lost in the papillate cells, the de-branched RG-1s become more sticky molecules, but are also able to re-mobilize from the papillate cell wall into the adhesive.

Conclusion

- Virginia Creeper tendrils produce adhesive pads that allow it to adhere to many objects, facilitating the climbing of the vine up even relatively flat and smooth objects.
- Immunolabeling indicates that the papillate cells are greatly elongated, but impoverished of many cell components, especially the side chains of RG-1. These same components are enriched in the adhesive itself, indicating their modification and re-mobilization to form the adhesive.

Figure 1

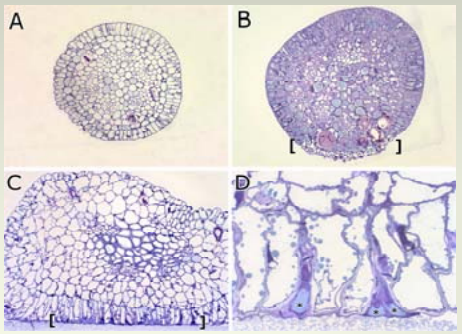

Figure 2

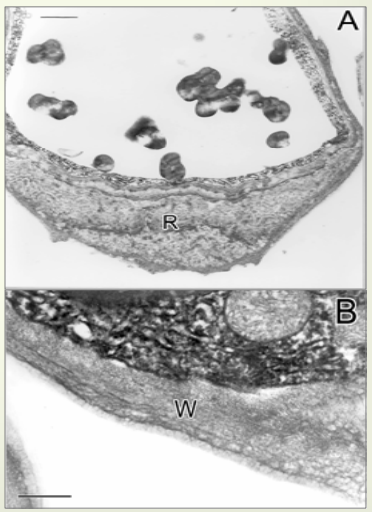

Figure 3

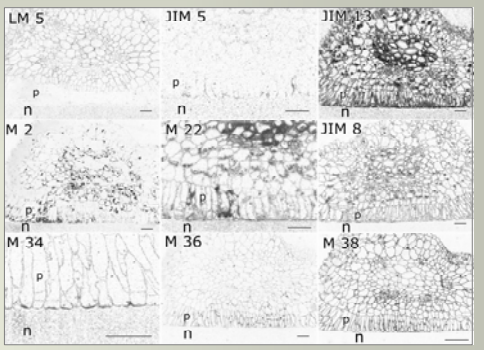

Figure 4

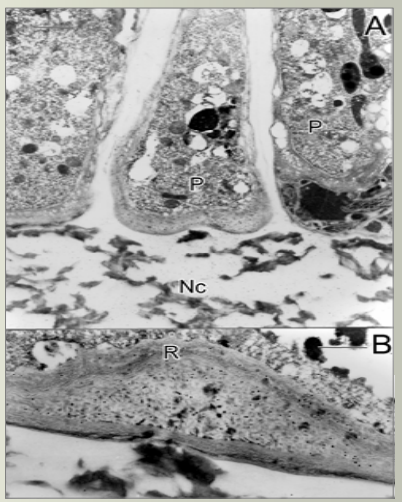

Figure Legends

Figure 1. Light micrographs of young (A, B) and mature (C,D) Virginia Creeper tendrils. The young tendril (A) is iso-bilateral, although after touch stimulation (B), a small group of differentiated cells and an overall shape change may be noticed (brackets). After the tendril has made contact, a zone of papillate cells (p) develops along the edge of the nitrocellulose that we have used as a support (C). Within and between the papillate cells, an extensively stained and heterogeneous zone of adhesive is noted (D). Bars = 50 µm.

Figure 2. Electron micrographs of papillate cells. (A) A low magnification micrograph of a papillate cell just before contact with the nitrocellulose. Note the raft of (R) highly heterogeneous wall and adhesive material at the base. (B) In contrast to the thickened basal wall, the side walls of the papillate cells are pitted, indicating a loss of contents.

Figure 3. Immunogold-silver localizations of wall epitopes in sections from the same block face to those shown in Fig 1C and 1D. Although the antibody to RG-1 side chains (LM 5) shows weak labeling in the papillate cells (p), antibodies to the RG-1 chain itself (M2 and 22), and antibodies to pectinaceous (RG-1 type) mucilage (M34, M36, M38) are highly enriched in the papillate cells and/or the adhesive layer. In addition, antibodies to AGP's are enriched in both the papillate cells and the adhesive. Bars = 50 µm.

Figure 4. Immunogold localizations of AGP's (A) and callose (B) in the papillate cells of Virginia Creeper. (A) The papillate cells (p) are strongly labeled towards their base and including the raft at the bottom of the cells, but are impoverished at areas away from the contact zone. In addition, AGP reactivity is found between the cells and escaping for almost 100µm into the nitrocellulose (NC). (B) Callose occurs in the raft at the base of the papillate cells, but is enveloped in a zone enriched in pectinaceous mucilage and AGP's. Bars = 1.0 µm in (A), 0.5 µm in (B).