Wireworms on wacky-backy:
how the biomechanics of lignin modified tobacco roots influences root herbivory

Scott N. Johnson[1], Paul D. Hallett[1], Trudi L. Gillespie[1] and Claire Halpin[2]
[1]Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA, U.K.
[2]School of Life Sciences, University of Dundee, Dundee DD 1 5EH, U.K. E-mail: Scott.Johnson@scri.ac.uk
Web: www.scri.ac.uk/ScottJohnson.htm

Scottish Crop Research Institute

University of Dundee

Introduction

Host plant suitability for insect herbivores is influenced by the biomechanical properties of plant tissues, yet these relationships are only known for aboveground plant parts and insects. Virtually nothing is known about how the biophysical properties of roots affect belowground insect herbivores. We used root-feeding wireworms (*Agriotes* spp.) and tobacco (*Nicotiana tabacum*) plants as a model system to explore whether root toughness could be manipulated and how this affected the ability of wireworms to penetrate root tissue.

The tobacco plants were either unmodified wild-types **(WT)**, or had transgenes introduced for down regulation of crucial enzymes[1-3] in the lignin biosynthesis pathway, specifically:

- cinnamyl alcohol dehydrogenase **(CAD)**,
- cinnamoyl CoA-reductase **(CCR)**,
- cinnamyl alcohol dehydrogenase and caffeate O-methyltransferase **(CO)**.

Testing root biomechanics

The fracture toughness of the roots was determined in tension test using an Instron mechanical test frame (Fig. 1). A ‘crack’ was cut into the roots to allow for fracture mechanics analysis and to control failure conditions.

This provides an indication of how easily wireworm mandibles (Fig. 2) might fracture roots.

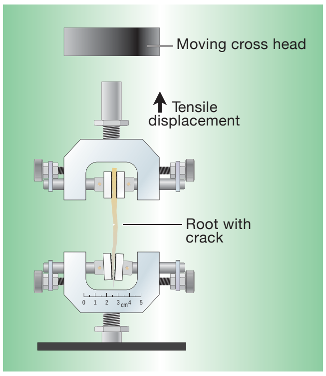

Fig. 1. Instron mechanical test frame

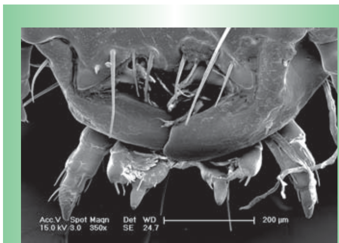

Fig. 2. SEM of wireworm mandibles

Bioassay with wireworms

Wireworms were placed in the top (exposed chamber) of bioassay cages (Fig. 3) in which a 30mm length of root section (diameter 2mm) was fixed into a central channel that separated the two chambers. This forced wireworms to chew through the section of root to enter the darkened moist chamber.

Time-lapse photography was used to record the time taken for wireworms to successfully chew through the root section.

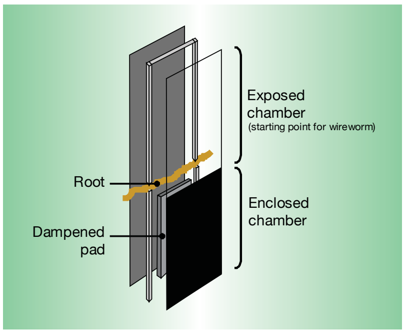

Fig. 3. Wireworm bioassay cage

Results and Discussion

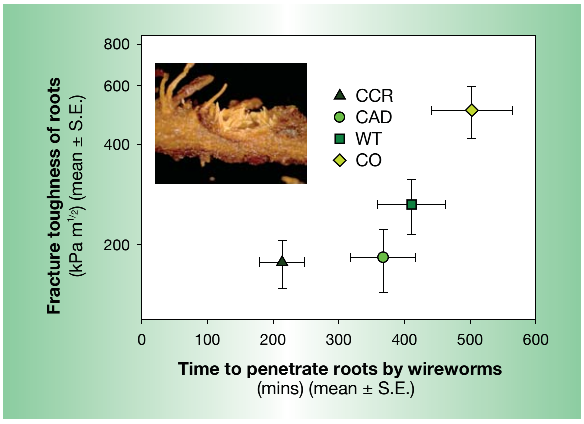

Fig. 4. Relationship between fracture toughness and root penetration by wireworms.

The different tobacco lines provided a model system with a range of fracture toughnesses ($P < 0.001$). There were also differences between lines in the time taken for successful root penetration by wireworms ($P<0.001$), which increased with fracture toughness (Fig. 4). In particular, those plants down regulated for production of cinnamoyl CoA-reductase **(CCR)** had the smallest fracture toughness and were the most quickly penetrated by wireworms in bioassays.

These preliminary findings suggest that plant biomechanical properties could significantly affect herbivores feeding belowground, and provide the basis for future research into how lignin content and composition of roots might influence root herbivory.

References

1. Abbott *et al*., (2002) Simultaneous suppression of multiple genes by single transgenes. Downregulation of three unrelated lignin biosynthetic genes in tobacco. Plant Physiol. 128, 844-853.
2. Halpin *et al*., (1994) Manipulation of lignin quality by down-regulation of cinnamyl alcohol dehydrogenase. Plant Journal 6, 339-350.
3. O’Connell *et al*., (2002) Improved paper pulp from plants with suppressed cinnamoyl-CoA reductase or cinnamyl alcohol dehydrogenase. Transgenic Res. 11, 495-503.