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TEXTURAL AND TASTE INFLUENCES ON GNAWING BY PINE VOLES

Lynette A. Geyer
Monell Chemical Senses Center, Philadelphia, PA

James N. Cummins
New York State Agricultural Experimental Station, Cornell University, Geneva, NY

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Lynette A. Geyer
Assistant Member
Monell Chemical Senses Center
3500 Market Street
Philadelphia, PA 19104

James N. Cummins
Associate Professor of Pomology
New York State Agricultural
Experimental Station
Cornell University
Geneva, NY 14456

ABSTRACT: Pine voles and meadow voles exhibited differential preferences for various Malus clones. When damage to dormant stems in a 24-hr test was assessed by either a graded damage scale or percentage consumption by weight, pine voles preferred Golden Delicious, M.9, and M.26 and consistently avoided M.x sublobata PI 286613 ("613") and related clones and Robusta 5. Dehydrating stems magnified the disparity among cultivars, as attractive stems continued to suffer extensive damage, while 613 became even less palatable. In the autumn phase all varieties showed increased acceptance. Meadow voles, like pine voles, exhibited differential acceptance of cultivars, but their preferences differed somewhat from pine voles in that they extensively damaged Robusta 5.

When bark and pulp portions of rootstocks were separately presented to pine voles in 1 hr tests, weight consumed followed expected varietal preferences. With dormant stocks, significantly more bark was consumed than pulp in both 613 and Golden Delicious samples, and, in both fractions Golden Delicious was consumed more than 613. In autumn-cut stocks Golden Delicious was preferred to three other varieties overall, as was its pulp fraction.

Humans readily detected textural contrasts among rootstocks, some of which can be measured during the dormant phase as lower densities and higher water content for the extremely preferred rootstocks. Humans also reported taste differences among cultivars, describing rootstocks and fragments as bitter more often for Golden Delicious and 613 than for Robusta 5 and M.9. Taken together, these rootstock data suggest that stem texture may be a primary factor for rootstock acceptability.

Taste probably also plays a role in rootstock preferences. Pine dowels soaked in fruit extract, sucrose, or quinine solutions or water or oil and individually presented to paired pine voles for 24 hr tests were gnawed differentially with enhanced gnawing for oil and extract-treated dowels, and less gnawing of quinine-treated dowels.

INTRODUCTION: Pine voles and meadow voles may inflict serious damage on apple trees by gnawing roots and bark (2). Whether voles gnaw to wear down their teeth, to obtain certain minerals, nutrients, or water, or to create nesting material, is unknown. Pine voles do consume some apple tree root tissue, as it is commonly present in stomach contents of wild-caught pine voles, but the percentage of apple root epidermis tissue in total stomach contents is very low, usually only a few percent (4), suggesting that apple roots, even in the winter, are not an important food source.

In this paper I present data regarding factors influencing gnawing of wood by voles, describing in the first section studies of acceptability in 24 hr tests of dormant, dormant and dried, dormant and sprouted, and autumn-cut *Malus* shoots. The acceptabilities of cortex and pulp portions of several cultivars in 1 hr tests are compared. Physical characteristics of the most and least attractive cultivars are described in the second section, including changes with season, and differences in taste quality as described by humans. In the third section I report effects of tastants on gnawing of pine dowels by pine voles.

ACCEPTABILITY OF ROOTSTOCKS TO VOLES: Both in the laboratory and in the field, voles have exhibited differential preferences among *Malus* clones (3,7,9). 'Golden Delicious' stems, for example, have consistently been more subject to damage than 613 stems.

For the present study, plant material was collected at Geneva, New York, either while fully dormant in January or before leaves dropped in October, shipped to Philadelphia, and there stored in plastic at 1°C until use within 30 days.

Pine voles were laboratory-born in a colony originally trapped in Pennsylvania in 1972, and meadow voles were wild-caught in Virginia a few months prior to tests. All voles were housed in plastic shoe box cages as heterosexual pairs and offered water, apples, alfalfa, peanuts, and sunflower seeds continuously throughout all experiments.

For an initial replication of Byers' study under our laboratory conditions, 20 pairs of pine voles were, in a series of weekly tests, presented with 15 cm rootstock lengths for a 24 hr period. A modification of Byers' damage rating scale (2) was used: 0 = no damage; 1 = 1/4 girdled; 2 = 1/4 - 1/2 girdled; 3 = 1/2 or more girdled; 4 = girdled; 5 = shortened or cut in two; 6 = consumed. In this study, wide variability occurred and no significant difference was found among M.26, M.9, Robusta 5, and 613 (3/76 df, $F = 1.23$); however data suggested a trend of lower acceptability for 613.

In a subsequent test using dormant stock and 23 *Malus* clones, significant differences were evident (22/90 df, $F = 1.86$, $p \leq .05$), with mean damage scores above 5 for 7227R5-181, M.27, 74R5M9-934 and M.9, and below 4 for 746363-32, 710663-1, 74R5M9-794, 74R5M9-5, 716325-2, 710663-13, the two extremes representing significant differences in t-tests.

Much later we obtained autumn-cut shoots, and a far higher percentage by weight was consumed (Fig. 1b) than for dormant material (Fig. 1a). In the autumn, 613 and Golden Delicious were significantly preferred over Robusta 5, indicating a positive shift in the attractiveness of 613. Dormant shoots which had been dried (150°C) for 3 days also significantly differed (25/159 df, $F = 3.36$, $p < .001$) with scores above 4.5 for 74R5M9-789, 75M9R5-47, 746363-75, and GD and below 3 for 7527R5-181, M.27, 710663-13, 74R5R5-29, 74R5R5-16, 74R5R5-15, 63, 746363-37, Rob. 5, 74R5M9-936 and 74R5M9-794. Shoots of 7 cultivars were then placed in a room at 20°C with an 18 L-6D cycle for 2

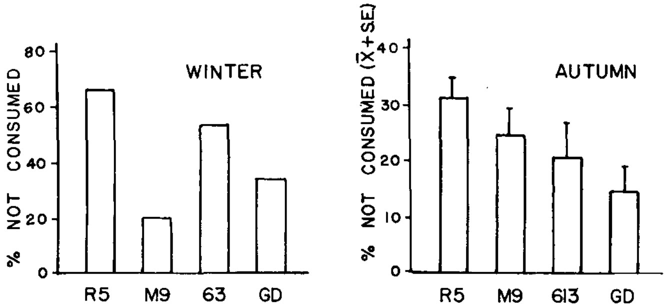

Figure 1. Percentage of Malus shoot weight not consumed by pine vole pairs. (Four cultivars were individually presented for 24 hr tests. In Fig. 1a, shoots were fully dormant. In Fig. 1b, leaves were removed before testing.)

weeks and allowed to develop leaves. Sprouted shoots were then presented to pine voles; damage differed significantly among cultivars (6/35 df, F = 4.29, $p < .005$), with high damage scores for 746363-51, 746363-37, 74R5R5-15, and M.27 and low scores for 74R5R5-16 and 613.

The average damage score for fresh dormant varieties pooled was 4.23 (S.E. = .18, 23 varieties) while dry dormant was 3.25 (S.E. = .25, 26 varieties), and dormant sprouted was 4.5 (S.E. = .37, 7 varieties). Drying reduced damage significantly while sprouting did not significantly affect damage. Individual cultivars had a significant reduction in damage after drying (sign test: n = 20, $p < .058$).

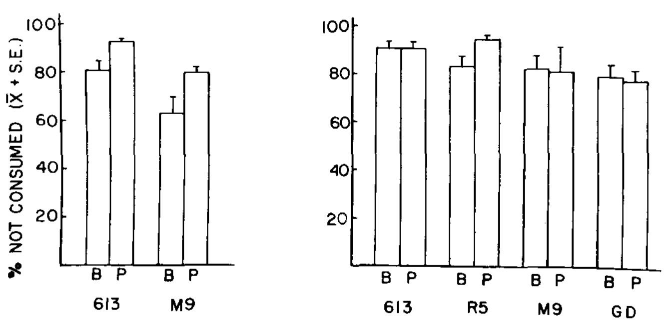

Figure 2. Percentage of shoot fractions, bark (B) and pulp (P), not consumed by pine vole pairs. (In Fig. 2a, dormant fractions were presented for 24 hr immediately after preparation. In Fig. 2b, autumn fractions were presented for 1 1/2 hr beginning 24 hr after preparation.)

To assess the attractiveness of dormant shoots, pieces were prepared from the colored layers of the bark and the white pulp. Portions of either bark or pulp from 613 or M.9 were weighed and presented to familiar pine vole pairs in a clean cage for a 2 hr test. Control samples of each variety were placed in clean empty cages and weighed after testing to permit correcting weights for percent water loss during the test period. More bark than pulp was consumed in both cultivars (1/16 df, $F = 16.63$, $p < .001$), and 613 was less palatable than M.9 (1/16 df, $F = 6.04$, $p < .05$; Fig. 2a). A similar experiment was later conducted using autumn-cut shoots. Uniformly-sized shavings (approx. 3 cm x 5 mm) were presented in 1.5g allotments the day after preparation. Control samples permitted corrections for drying. Each vole pair was given 3 tests in a repeated measure design with randomized selection of treatment. The autumn-cut stems differed with respect to variety (3/48 df, $F = 17.6$, $p < .001$; Fig. 2b), portion of the rootstock (1/48 df, $F = 9.4$, $p < .001$) and the interaction (3/48 df, $F = 5.88$, $p < .005$). There was a significant order effect, with scores increasing on subsequent tests (2/48 df, $F = 17.6$, $p < .001$) and an interaction among variety, stem portion, and order of testing (6, 48 df, $F = 14.7$, $p < .001$). Compared to other varieties, Golden Delicious was significantly preferred overall, and its pulp was preferred to others (t-tests $p < .05$). Robusta 5 bark was significantly preferred to its pulp; this is consistent with the frequent stripping off of bark which occurs when whole Robusta 5 stems are presented.

Meadow voles also exhibit varietal preferences, but they are unlike pine voles in their relative liking for Robusta 5 (Fig. 3b). Negative results have occurred in studies of acceptability of (1) leaves of various cultivars; and (2) supernatant from pulverized shoots of various cultivars in water, with or without sucrose.

Acceptability of apple shoots was influenced by cultivar, by the stem hydration, and by the stem fraction. While these factors significantly affect rootstock damage in the laboratory, substantial consumption occurred even under the least attractive conditions. Orchardists can probably benefit most by selecting unattractive rootstocks as part of an integrated vole control program.

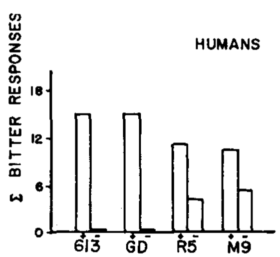

Figure 3a
Perception of Malus shoots by a human taste panel. (Six women were presented with bark, pulp, and whole shoots of 4 varieties and asked to describe tastes of each.)

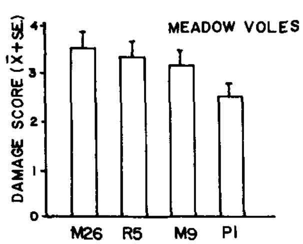

Figure 3b
Damage to Malus shoots by meadow vole pairs.

PHYSICAL CHARACTERISTICS RELATING TO ACCEPTABILITY: Several factors may indicate whether taste is an overriding determinant of rootstock acceptability. Succulence and textural factors probably vary with season and apparently change palatability, since dehydration influences acceptability of many cultivars, as shown in the previous section. Some seasonal changes in taste are also likely and may be critical to acceptability.

Golden Delicious is highly preferred by pine voles whether fresh dormant or dried dormant. Pine voles avoid the bitter taste of quinine in liquid taste preference tests (1). To a human taste panel of 6 women rating autumn-cut apple shoots, bark, and pulp, Golden Delicious and 613 were significantly more bitter than Rob. 5 and M.9 (Fig. 3a). For voles then, Golden Delicious palatability may be a function of some quality other than taste.

More evident to humans are the textural differences among clones. An attempt to break a shoot can result in a simple snap of the twig as if it were already serrated, or can produce a struggle with long fibrous strings which are not easily broken or cut. To test these textural differences, we measured: (1) the density of many *Malus* cultivars by water displacement and (2) the percentage dry weight.

Densities significantly increased, on the average, from winter dormant to autumn ($\bar{X}$ = .99, 1.12, respectively). Density values in autumn did not relate to acceptance by voles or ease of breaking shoots, however densities of dormant shoots were related to extremes in acceptability or its absence. Five cultivars appeared in the top and five in the bottom of acceptability in at least two of four dormant measures (damage scores for fresh, dry, sprouted; percentage consumption for fresh). The five highly acceptable varieties (Golden Delicious, M.9, 74R5M9-755, 7527R5-181, 74R5M9-934) had lower densities ($\bar{X}$ = .97 $\pm$ .01) than the highly rejected cultivars (746363-37, 613, MM.106, 746363-32, Rob. 5; $\bar{X}$ = 1.03 $\pm$ .02).

The percent dry weight also changed with season, increasing from the autumn ($\bar{X}$ = 45.4 $\pm$ .02, n = 32 cultivars) to the dormant season ($\bar{X}$ = 56.3 $\pm$ .01; n = 32 cultivars). Again, the dormant shoots differed in percent dry-weight at acceptability extremes. The five most acceptable clones had lower percent dry weights ($\bar{X}$ = .52 $\pm$ .01) than the five least acceptable ($\bar{X}$ = .59 $\pm$ .01).

These data implicate textural differences as important in rootstock acceptability. Comparative studies of wood structure and anatomy and seasonal changes are needed to clarify the bases of contrasts in density and dry weights.

TASTE INFLUENCES ON GNAWING: In this experiment we standardized the textural properties of the substance and added tastants to determine whether gnawing is affected by taste. Wooden pegs were soaked for 3 days in flavorants shown in previous work to affect preference: .05 M quinine hydrochloride (1), 1.4 M sucrose (1), 25% fruit extract DRC-470 (8), corn oil (5,6), or a water control. Pegs were weighed and then presented to 10 pine vole pairs for a weekly 24 hr test in a two-way repeated measured design. As a drying control, wet pegs were allowed to air dry in an unoccupied cage during the test period.

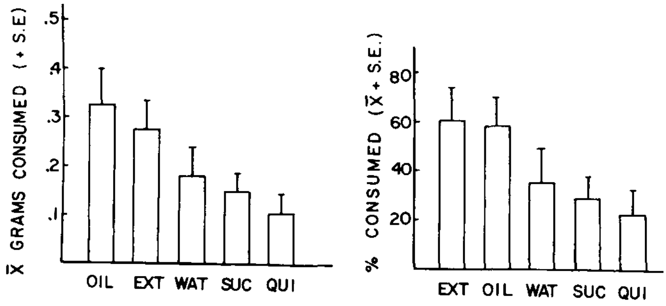

Figure 4. Consumption of wooden pegs by pine vole pairs while gnawing. [Pegs were soaked in fruit extract (EXT), sucrose (SUC), or quinine (QUI) solutions or water (WAT) or corn oil (OIL) for 48 hr and then presented individually for 24 hr tests.]

Dowels were reweighed at the end of the test and weights corrected for drying. Fig. 4 shows that oil and extract-soaked pegs were significantly preferred to quinine, also oil to sucrose (Fig. 4a: ANOVA, 4/63 df, F = 3.54, $p < .025$; t-tests, $p < .05$), and extract to sucrose (Fig. 4b; ANOVA, 4/36 df, F = 5.38, $p < .005$; t-tests, $p < .05$).

These data verify that tastants can enhance gnawing by pine voles. Most surprising was the low acceptability of sucrose-treated pegs, since sucrose in liquid preference tests is a highly-favored flavor.

CONCLUSIONS: Taken together, these experiments highlight the complexity of apple rootstock acceptability to voles and suggest that texture and taste factors are both critical to acceptability. Further studies could elucidate the feasibility of enhancing or depressing acceptability of rootstocks by adding various tastants, and thereby quantitatively distinguish roles of texture and taste. In addition to probable synergistic interactions among rootstock characteristics, the condition of the voles is another variable not tested here. Influences of hunger, diet variety, age and reproductive status, thermal stress, and food or water deprivation in voles on rootstock acceptability are likely to be as significant as variety resistance.

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