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Vertical-Lift Potential of the Trapped *Hypochaeris radicata* (*Catsear*), a Phototropic Sub-Pavement Plant

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Research Article

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ABSTRACT

The remarkable vertical lifting power of sub-surface driveway plants has been measured. The *Taraxacum officinalae* plants, working in buckling mode, can bend, lift, crack, and penetrate a 3 inch [6 cm to 8 cm] asphalt-macadam driveway surface (N=20 plants). The maximum vertical-lift capability of the 2-stem *Taraxacum officinale* was measured at 3-lbf (1.4 Kg). By comparison, the considerably stronger 3-stem *Hypochaeris radicata* (Catsear) was measured at 18 lbf (8.2 Kg) (N=1 plant). The remarkable ability of these plants to respond to extreme vertical loading conditions, is potentially an important laboratory model of mechanosensing. A 12-stem *Hypochaeris radicata* (Catsear) (N=1 plant) is observed, having penetrated a similar macadam sidewalk surface. Only the multi-stem Catsear is powerful enough to break through 3" to 4" (7 cm to 10 cm) of asphalt-macadam sidewalk. The driveway Catsear demonstrates F_{crit}=18-lbf. (8 Kg, N=3 stems) whereas the considerably stronger sidewalk catsear is estimated at F_{crit}=70-lbf. (32 Kg, N=12 stems) maximum vertical lifting force. This does not include the extra vertical force available from the leaf stems (N>24 leaves). These values approach feasibility, in terms of the integrated load-deflection work, required to bend and crack the pavement, deflecting the surface upwards 2.5 cm. Also reported are the phototropic behavior of the *Hypochaeris* plant throughout the day, and stem re-growth at the rate of 0.3 m/wk. (N=200 plants).

INTRODUCTION

Sub-surface driveway plants. The remarkable vertical lifting power of sub-surface driveway plants has been measured [1]. The comparatively weak Taraxacum officinale plant, working in buckling configuration, is able to bend, lift, crack, and penetrate a 3 inch (6 cm to 8 cm) asphalt-macadam driveway surface (N=20 plants). The maximum vertical-lift capability of the 2-stem Taraxacum officinale was measured at 3-lbf (1.4 Kg), as shown in the **Figure 1** [1]. By comparison, a considerably stronger 3-stem Hypochaeris radicata (Catsear) was measured at 18-lbf (8.2 Kg) [1]. The remarkable ability of these plants to respond to extreme vertical loading conditions, is potentially an important laboratory model of "mechanosensing" [1].

MATERIALS AND METHODS

The Taraxacum and Hypochaeris Variants

The *Taraxacum officinale* plant is a common short-stem domestic dandelion plant which flowers during the month of May here in the northeastern United States. The *Hypochaeris radicata* (Catsear) variant is a long-stem wild dandelion, flowering during the month of June. The Young's modulus E for Taraxacum stems in tension has been measured, and from this value, stem buckling load can be calculated using the Euler equation [1,2]. Young's modulus in compression for the catsear, a much stronger plant, is found to be 100 times stiffer [1]. Preliminary load-deflection measurements of the macadam surface indicate that approximately 10 times more force than measured, for either of these plants, is required to penetrate the 3 inch (6 cm to 8 cm) asphalt-macadam surface, shown in the **Figure 1a.**

Maximum Vertical Lift

Nearby, a 12 stem *Hypochaeris radicata* (Catsear) plant is observed, having penetrated a similar macadam sidewalk surface **(Figure 1b).** Along the crack between the sidewalk and the stone wall, several "conventional" Taraxacum plants are observed,

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able to squeeze into the gap, but not strong enough to fracture the surface, as did the catsear plant in **Figure 1b.** Only the multi-stem catsear is powerful enough to break through 3 to 4 (7 cm to 10 cm) of asphalt-macadam sidewalk.

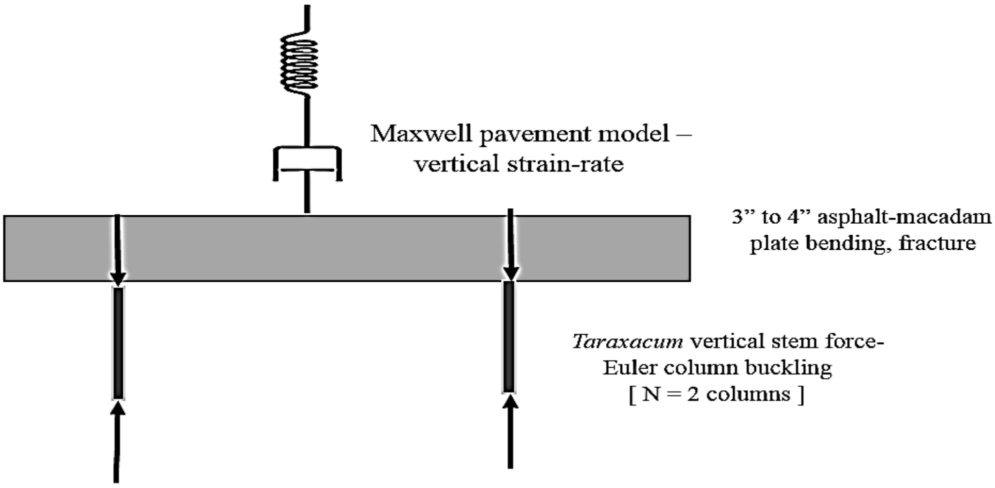

Figure 1a. Schematic diagram of the plant-surface interface. Maxwell strain-rate model predicts surface deflection rate over time, as a function of vertical lifting force, provided by *Taraxacum* stems, in Euler buckling configuration.

Figure 1b. 24-inch tall (0.6 meter), 12-stem Hypochaeris radicata catsear plant, having penetrated an asphalt-macadam sidewalk. The vertical lift capability of plant estimated at a remarkable 70-lbf (32 Kg). The flowers demonstrate the "positive phototropic effect".

Locale

The sidewalk and driveway experiments are observed in Huntington, NY. The phototropic effect is observed in Riverhead, NY, at approx. the same latitude 410 N.

RESULTS AND DISCUSSION

Required Vertical Force

The driveway Catsear demonstrates F_{max}=18-lbf. (8 Kg, N=3 stems) whereas the considerably stronger sidewalk Catsear is estimated at F_{max}=70-lbf. (32 Kg, N=12 stems) maximum vertical lifting force [1]. This estimate does not include the extra vertical force available from the catsear leaf stems (N>24 leaves). These vertical force values marginally approach feasibility, in terms of the integrated load-deflection work, required to bend and crack the surface upwards 1 inch (2.5 cm) [1]. Thus, at least some of the multi-stem Hypochaeris plants demonstrate the heavy lift capability necessary to bend and fracture a macadam pavement. Still, the remarkable ability of the weaker domestic Taraxacum to break a driveway surface remains an unsolved challenging problem in the fields of applied mechanics and bioengineering [1].

The Phototropic Catsear

As shown in **Figure 2**, one of the unique properties of the wild *Hypochaeris* (not demonstrated by the domestic *Taraxacum* plant) is the so-called "positive phototropic effect", during the late AM until the early PM hours, during which the flowers open, for 6 to 8 hours. (This interesting phototropic effect has undoubtedly been reported elsewhere, but as of this writing, we have not found a similar journal reference). **Figure 1b** shows the open-flower configuration, starting during the period 8-10 AM (D S T) followed by the closed-flower position, during the interval 4 to 6 PM (D S T). This phenomenon has not been studied here completely, due to

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enthusiast lawn mowing, officially authorized. N=4 plants are observed that do rotate, so as to follow the sun, and another N=2 plants, once in the shade, close their flowers. In bright sunlight, the flowers, for some reason, close by 4:00 PM. However, on an overcast day, the flowers remain open at 4:00 PM.

Figure 2. The *catsear's* photo-sensitive flowers close during the late afternoon hours, from 4 to 6 PM (D S T), demonstrating the phototropic effect. Same plant as shown in **Figure 1**, during the same day.

Re-Growth Rate (Regeneration Rate)

After having being mown within 2" (5 cm) of the ground, the Hypochaeris wild dandelion stems regrow at the remarkable rate of 1" to 2" per day (3 to 5) cm/d. Within 1 week, the new stems are complete, including the flower, growing to a height of 1 foot (0.3 m). Within 2 weeks, some of the plants have regrown to the original 2 feet (0.6 meters) in height. This regrowth or regeneration process has been observed to recur 3 or 4 times for each plant, every 2 weeks, over the course of the summer (N=200 plants). By comparison, once mown, the domestic Taraxacum stems do not seem to have this regrowth capability.

Other Similar Plants

Vander brink discussed the phototropic effect in sunflowers, whereby the plant stem rotates during the day, to follow the path of the sun [3]. Parendes and Jones observed that available light level is positively correlated with propagation of the Hypochaeris [4]. Whippo and Hangarter review phototropism, exhibited by many higher plants, including peas, mustard, oats, corn, and various types of fungi [5]. The Hypochaeris in **Figure 1b** was not observed to rotate following the sun as sunflowers do, however, most of the flowers face north **(Figure 1b).** Perhaps one can make the case that the open-field Hypochaeris plants do rotate, but we have not studied this systematically yet [4]. Positioned near a wall, having the flowers facing north is the optimal average orientation to collect light, as shown in **Figures 1b and 2.**

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