STRATEGIES FOR REDUCING WATER INPUT IN WOODY LANDSCAPE PLANTINGS

by A.M. Smith and D.A. Rakow

Abstract. One meter (3 ft.) tall whips of *Fraxinus pennsylvanica* 'Emerald' (pubescent), *Fraxinus pennsylvanica* (glabrous), *Malus* 'Klehm's Improved Bechtel' (pubescent) and *Malus* "White Angel (glabrous) were used to evaluate the role of pubescence in plant water relations. All plants received the same watering regime and drying cycle. The *Fraxinus* showed a trend in which the pubescent cultivar maintained less negative predawn water potential. In *Malus*, the pubescent trees had less negative predawn water potintials. A comparison of four mulch types (shredded bark, fine bark, wood chips and medium grade gravel) to bare soil controls, showed that all mulch types resulted in less evaporational water loss. The shredded bark and medium grade gravel providing the greatest reduction in evaporational water losses. The pubescent *Fraxinus* cultivar 'Emerald' and a 4 cm (1.6 in.) layer of shredded bark mulch resulted in the least negative water potentials.

Additional Index Words: Pubescence, mulch, water efficient landscapes

In order for plants to survive a prolonged water stress, they must be able to prevent or reduce water loss in certain tissues. Hinckley et al. (4) stated that leaf adaptations appear to be a key in the success of a species in a water-stressed environment. Common adaptations include increases in cutinization, thickness of both the mesophyll layers and the entire leaf, and leaf pubescence. LoGullo, Salleo and Rosso (6) reported that plants growing in arid habitats tend to possess leaves that have more pubescence than similar or related plants growing in mesic habitats.

Pubescence allows a plant to maintain carbon exchange under arid conditions, helps the plant avoid lethally high leaf temperatures, and reduces daily water loss by maintaining a saturated boundary layer. All of these factors will extend the plant's growth for a longer period of time (7).

The application of a mulch layer will also improve the water status of landscape plants. A mulch is any material applied to the soil to moderate or increase soil temperature, conserve soil moisture, or to suppress weed growth (3). Einert et al. (2) reported in a study comparing various mulch materials with bare soil that the soil moisture percentages in mulched plots were approximately twice as high as the bare soil plots, the summer soil temperatures were reduced by eight to 13 degrees (F), and the average time required to remove weeds was reduced by two-thirds. Mulches also reduce the impact of water droplets hitting the soil surface, thereby reducing soil erosion and crusting. This reduction in soil crusting increases water penetration into the soil.

Current recommendations call for the application of an organic mulch layer which is 4 to 10 cm (1.6-4.0 in.) deep (5). A layer of mulch deeper than this may reduce oxygen and water penetration into the soil (1), and this will ultimately reduce plant and root growth. The primary objectives of this research were to evaluate: 1) the role of leaf pubescence in increasing tolerance in selected woody ornamentals to imposed water stress, and 2) the effect of mulch type and depth on reducing soil evaporative losses.

Materials and Methods.

Experiment 1. The first experiment contrasted glabrous leafed *Fraxinus pennsylvanica* with pubescent *F. pennsylvanica* 'Emerald, and glabrous leafed *Malus* 'White Angel' with pubescent *M.* 'Klehm's Improved Bechtel'. All bareroot whips were pruned to .9 m (3.0 ft) above the graft union and the roots were standardized to a 50 cm (20 in) diameter circle. Each was then planted in a 38 L (10 gal.) black plastic container in a 1:1:1 (by volume) perlite, peat, sandy loam soil medium.

Six replicates of each tree type were given one of three treatments: one 7 day dry period (Group A), two seven day dry periods separated by a rewatering (Group B), or no dry periods (Group C)

(Table 1).

Using a Sholander-type bomb, baseline predawn water potentials were taken on a single fully expanded leaf from each plant at the beginning of the experiment. After each of the 7 day dry periods was over, predawn water potential readings were again taken. To determine leaf hair density, two leaves were chosen randomly, one near the top and one near the middle, from each tree of the three treatments. A clear plastic sheet with a 10 cm by 10 cm (4 in by 4 in) grid was laid over each leaf and two different counts of leaf hairs were taken. All of the readings within a cultivar were then averaged.

A completely randomized design was used with 6 replicates/ treatment/ cultivar. The greenhouse was maintained at 21°C day/16°C night temperatures. The data were analyzed through factorial analysis using the PROC-GLM procedure of SAS (SAS Inst. Inc., 1985, Cary, NC).

Experiment 2. In the second experiment, sixty-four 20 L (5.2 gal) black plastic containers were filled to a height of 30 cm (12 in) with a sandy loam soil then covered with either a 3.8 cm (1.5 in) or 7.6 cm (3.0 in) layer of hardwood chips, shredded pine bark, fine pine bark, medium grade gravel or were left uncovered. All of the experimental units were saturated with water and, when gravitational flow had ceased, initial pot weights were taken. Pot weights were taken during the following 5 days to determine the daily water loss.

A completely randomized design was used with 8 replicates/ treatment. The greenhouse was maintained at 21°C day/16°C night temperatures. The final pot weights were subjected to a t test for significance at the 5% level using the MINITAB statistical package.

Experiment 3. The *Fraxinus* trees from the first experiment were standardized to a height 3 m above the bud union. Four trees from each cultivar were given one of the following treatments: shredded bark (4 cm depth), medium grade gravel (4 cm depth), a fused non-woven polypropylene geotextile (DeWill Weed Barrier), or no mulch treatment. A class A evaporation pan apparatus was used to determine water evaporated over a given time period. A preliminary test was run on non-mulched trees to determine that 2 cm (0.8 in) of water evaporated from the pan before a critical predawn leaf water potential threshold of -1.0 MPa was reached.

Baseline predawn water potentials were taken, and were repeated when 1 cm (0.4 in) and 2 cm of water had evaporated from the pan. All experimental units were thoroughly rewatered for two days and then a second dry down began. Predawns were taken at the onset, after 1 cm evaporated, and after 2 cm evaporated.

A completely randomized design was used with four replicates/ treatment. The greenhouse was maintained at 21°C day/16°C night. All of the trees were destructively harvested and the leaves run through a Leaf Area Meter (LiCor Model 3100). Analysis of variance was run on the mean leaf area of each tree. The data from the predawn and daily water potentials were analyzed through factorial analysis using the PROC-GLM procedure of SAS (SAS, Inst. Inc. Cary, NC).

Table 1. Three treatment groups with six cultivar replicates each of *F. pennsylvanica*, *F. pennsylvanica* 'Emerald', *Malus* 'WA' and *Malus* 'KIB'.

	Treatment		
Date	Group A	Group B	Group C
1/30-7-6	water	dry	water
7/7	water	rehydrated	water
7/7-7/13	dry	dry	water
7/14	rehydrated	rehydrated	water
7/14-7/20	water	water	water

Results and Discussion

Experiment 1. An examination of average leaf hairs/mm^2 revealed that *F. pennsylvanica* had zero hairs, *F. p.* 'Emerald' had 281; *M.* 'White Angel' had 21 hairs and *M.* 'Klehm's Improved Bechtel' had 163. There were significantly different leaf hair densities within each genus (Table 2).

The results presented here are from the two consecutive dry periods (Group B). The pubescent *F. p.* 'Emerald' displayed a non-significant trend toward less negative predawn water potential at the end of both dry downs compared to the glabrous *F. pennsylvanica* during the same dry periods (Figure

Table 2. Leaf hair density for *Fraxinus pennsylvanica, F. p.* 'Emerald', *Malus* 'WA' and *Malus* 'KIB'.

Cultivar	leaf hairs/mm^2
Fraxinus pennsylvanica	0
Fraxinus pennsylvanica 'Emerald'	281.0
Malus 'White Angel'	21.0
Malus 'Klehm's Improved Bechtel'	163.3

1). The pubescent *M.* 'KIB' maintained less negative, and therefore less stressed, predawn leaf water potential at the end of both dry periods compared to the glabrous *M.* 'WA' (Figure 2).

When contrasting the predawn water potentials of the two pubescent cultivars, the *Malus* 'KIB' maintained less negative predawns than did the *F. p.* 'Emerald'. The 'KIB' cultivar, with little more than half the leaf hair density of 'Emerald', reached a most negative water potential of -.60 MPa (Figure 3a). The 'Emerald' cultivar reached an average water potential of -1.96MPa after completing the same two week period of imposed drought (Figure 3b). These results suggest that, although leaf pubescence is one factor that can increase a plant's ability to withstand imposed drought stress, other factors, including total leaf area and tree architecture must also be considered.

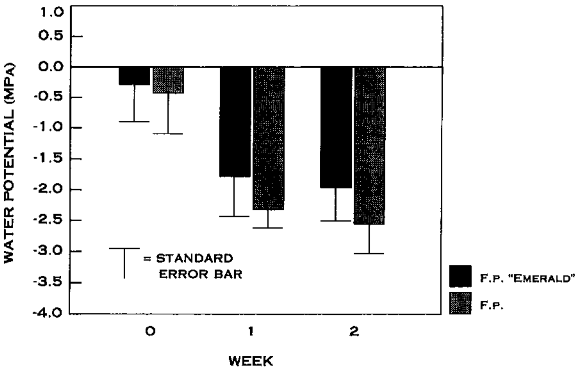


Figure 1. Average predawn water potential for Fraxinus pennsylvanica and F.p. 'Emerald' showing the results of no drought stress (wk 0), one week of imposed drought stress (wk 1) and two consecutive weeks of imposed drought stress (wk 2).

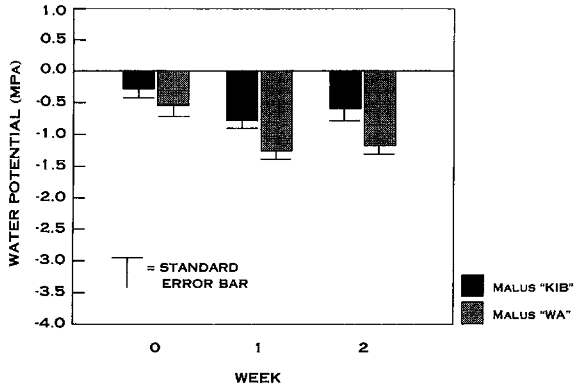
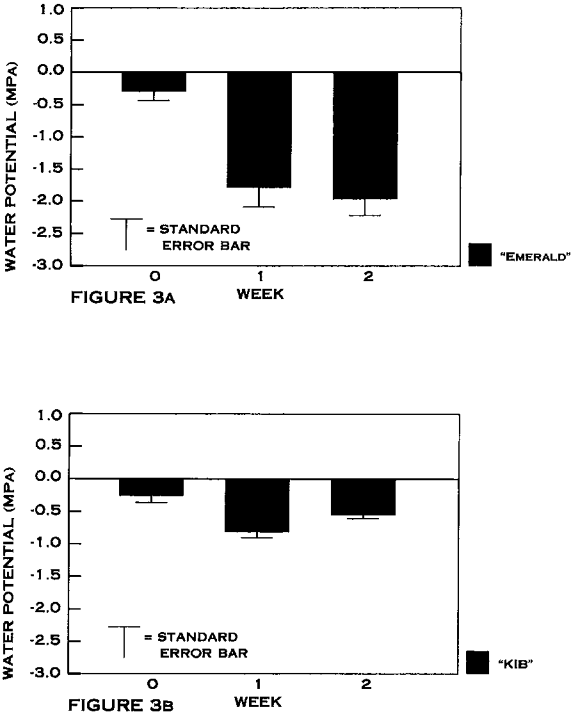


Figure 2. Average predawn water potential for Malus 'White Angel and Malus 'Klehms's Improved Bechtel' showing the results of no drought stress, one week of imposed drought stress and two consecutive weeks of imposed drought stress.



Figures 3a and 3b. Average weekly predawn water potential of pubescent Fraxinus 'Emerald' (3a) and Malus 'KIB' (3b) cultivars over two week treatment period. (week 0- no drought stress; week 1- one week of drought stress; week 2- two consecutive weeks of drought stress).

Table 3. Percent evaporative water loss saving by treatment and depth compared to control for shredded bark, gravel, wood chips and fine bark at depths of 3.8 cm and 7.6 cm, in 20 L containers.

Mulch type	Mulch depth 3.8 cm	7.6 cm
Shredded bark	43.8%	43.8%
Gravel	48.7%	52.6%
Wood chips	27.3%	26.7%
Fine bark	33.1%	35.9%

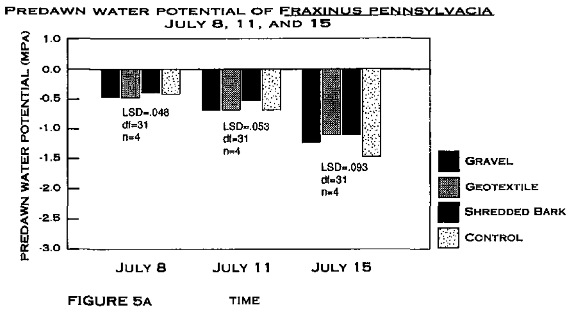
Experiment 2. The results from the mulching experiment showed that after a five day period there were no significant differences based on depth within each mulch treatment. However, the mulches did reduce evaporational water loss on average of 27, 34, 43 and 50% relative to the bare soil control (Table 3). The gravel and shredded bark results were similar for both application depths, and the wood chips and fine bark results were similar at both depths. The gravel and shredded bark conferred the greatest savings. The application of mulch layer of 3.8 cm resulted in the same benefits as a 7.6 cm layer. This suggests that the application of a 3.8 cm layer is not only more economical, but may also help to alleviate problems associated with over-mulching.

Experiment 3. The results from the third experiment, which combined tree type and mulch type, further supported the results from the first two experiments. Across all four treatments, the pubescent *F. p.* 'Emerald' trees maintained significantly less negative predawn water potential (by an average of -.16MPa) than the glabrous *Fraxinus pennsylvanica* after the first induced drought. Across both the species and cultivar, of the two particulate mulches — shredded bark and medium grade gravel — the shredded bark was associated with the least negative predawn water potential (Figure 4a and 4b).

At the end of the second consecutive dry down period, there was no difference in predawn water potential between the *Fraxinus pennsylvanica* and *F. p.* 'Emerald'. However, within the two groups there was a difference between the gravel and shredded bark mulches. The shredded bark mulch was again associated with the least negative water potential for both tree types (Figure 5a and 5b).

Conclusions

Creating landscapes using low water input and high water efficiency is becoming increasingly important to nurserymen and landscapers as many regions in the nation face drought-like conditions. This research suggests that species with the morphological characteristic of pubescence are able to maintain more favorable water status when compared to glabrous members of the same species. As well, the application of a 3.8 cm (1.5 in) mulch layer resulted in reduced evaporational water loss ranging from 27-50% relative to a bare soil control; and a 3.8 cm layer yielded essentially the same results as a 7.6 cm (3.0 in) layer, suggesting that the 3.8 cm application would be more economical. Appropriate species selection and the application of a suitable mulch are only two ways to help create



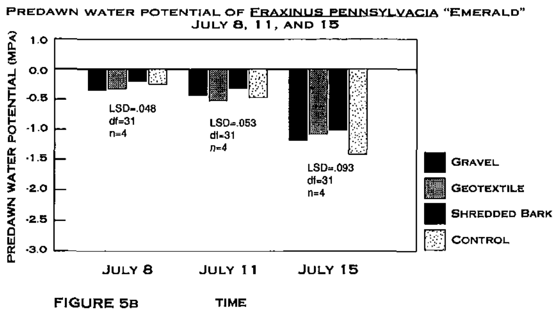
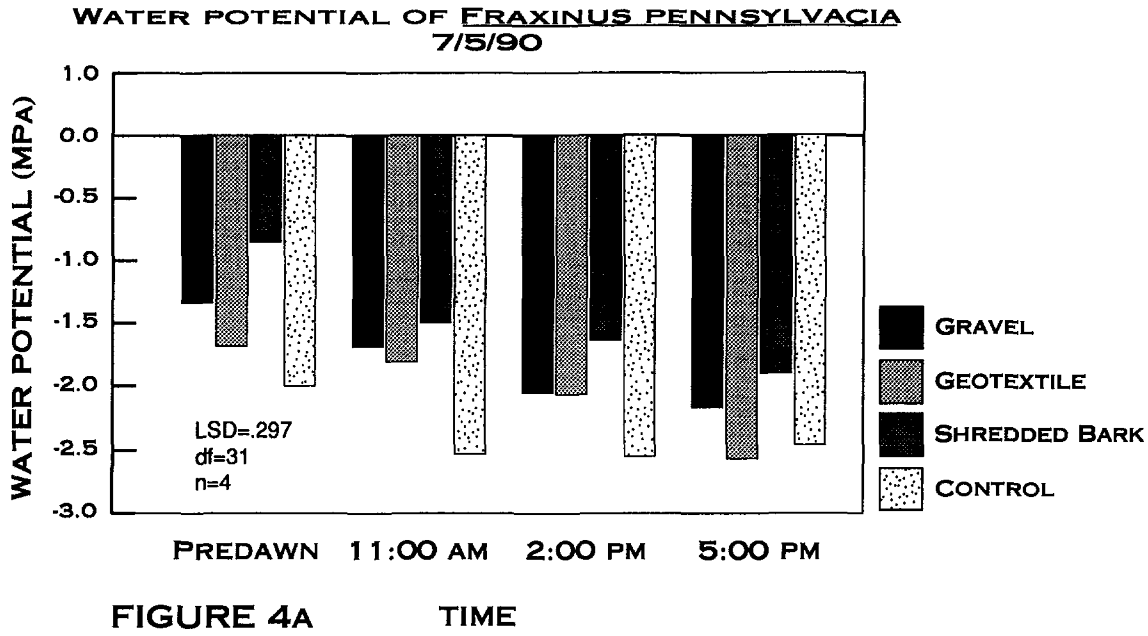


Figure 5a and 5b. Predawn water potentials of Fraxinus pennsylvanica (5a) and F. p. 'Emerald' (5b) across all mulch treatments on July 8, July 11 and July 15, 1990.



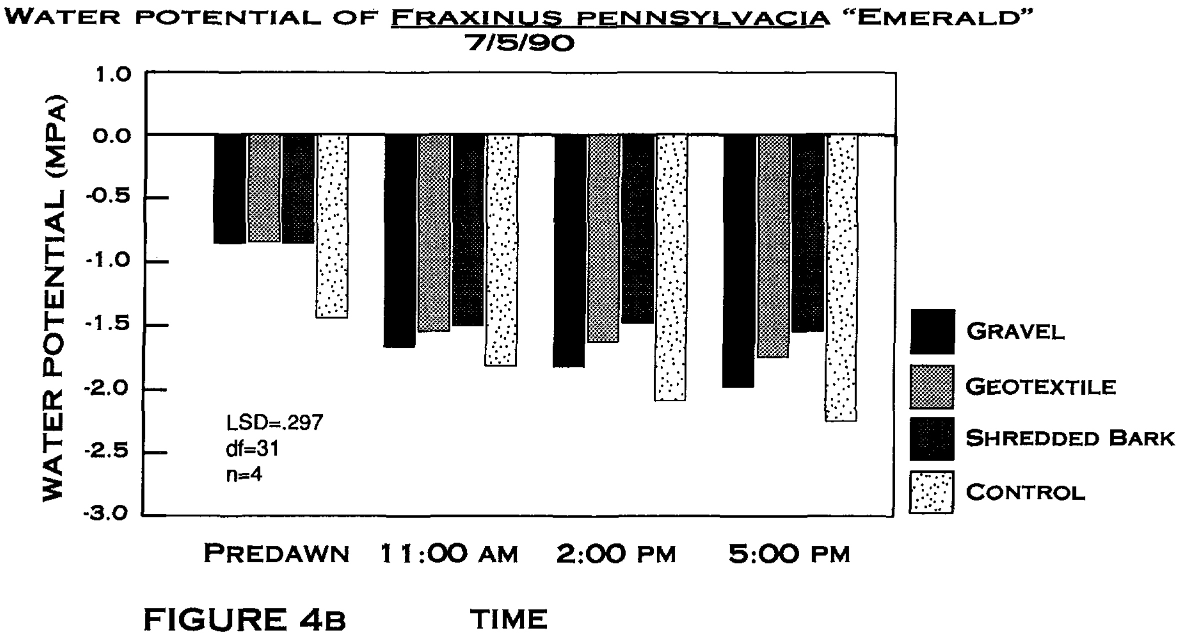


Figure 4a and 4b. Water potentials of Fraxinus pennsylvanica (4a) and F.p. 'Emerald' (4b) across four mulch treatments after 9 days dry cycle. Readings taken at predawn, 11:00 a.m., 2:00 p.m. and 5:00 p.m.

a water efficient landscape. This can result in a reduction in stress-related mortality of trees, help nurserymen and landscapers in drought-stricken areas to comply with water restrictions, and increase consumer satisfaction with plant performance.

Literature Cited

1. Billeaud, L.A. and J.M. Zajicek. 1989. *Mulching for weed control.* Grounds Maintenance 24(2): 11-16.
2. Einert, A.E. et. al. 1975. *Permanent mulches for landscape plantings of dwarf crape myrtles.* Amer. Nurseryman 142: 9, 59-61.
3. Harris R.W. 1991. Arboriculture: Integrated Management of Trees, Shrubs, and Vines. Printice-Hall, Inc., Englewood Cliffs, NJ.
4. Hinckley, T.M. et al. 1989. Physiological, morphological and anatomical components of hybrid vigor in "Populus". **In** Structural and Functional Responses to Environment Stress (199-217). Academic Publishing, The Hague, Netherlands.
5. Khatamian, H. 1985. *Mulching - how, when why and with what.* Grounds Maintenance 20(6): 102-104.
6. LoGullo, M.A., S. Salleo and R. Ross. 1986. *Drought avoidance stategy in "Ceratonia siliqua" L., a mesomorphic leaved tree in the xeric mediterranean area.* Ann. Bot. 58(5): 745-756.
7. Turner, N.C. and P.J. Kramer. 1980. Adaptation of Palnts to Water and High Temperature Stress. Wiley & Sons, NY.

Department of Floriculture and Ornamental Horticulture
20 Plant Science Building
Cornell University
Ithaca, New York 14853

Résumé. Des baliveaux d'un mètre (3 pieds) de hauteur de *Fraxinus pennsylvanica* 'Emerald' (pubescent), *F. pennsylvanica* (glabre), *Malus* 'Klehm's Improved Bechtel (pubescent) et *M.* 'White Angel' (glabre) étaient utilisés pour évaluer le rôle de la pubescence dans les relations plante-eau. Toutes les plantes recevaient le même régime d'arrosage et le même cycle d'assèchement. Le *Fraxinus* montrait une tendance où le cultivar pubescent maintenait des potentiels en eau, précédant l'aurore, moins négatifs. Chez *Malus*, les arbres pubescents avaient des potentiels en eau, précédant l'aurore, moins négatifs. Une comparaison de quatre types de paillis (écorce en résidus grossiers, écorce fine, copeaux de bois, gravier moyen) avec les sols nus témoins montrait que tous les sols avec paillis résultaient en des pertes d'eau par évaporation inférieures, l'écorce grossière et le gravier moyen réalisant les réductions les plus significatives des pertes en eau. Le cultivar de *Fraxinus* pubescent 'Emerald" et un paillis d'écorces grossières de 4 cm (1.6 pouces) d'épaisseur donnaient les potentiels en eau les moins négatifs.

Zusammenfassung. An 1 m langen Jungbäumen von *Fraxinus pennsylvanica* "Emerald" (pubescent), *Fraxinus pennsylvanica* (glabrous), *Malus* "Klehm's Improved Bechtel (pubescent) and *Malus* "White Angel" (glabrous) wurde der Einfluß der Geschlechtsreife auf den Wasserhaushalt untersucht. Alle Pflanzen wurden gleichartig bewässert. *Fraxinus* zeigte den Trend, daß die geschlechtsreifen Pflanzen geringe negative Wasserpotentiale aufrecht erhalten. Bei *Malus* hatten die geschlechtsreifen Bäume geringe Wasserpotentiale. Beim Vergleich von vier Mulchtypen (geschredderte Rinde, "fine bark", Holzschnitzel und mittelgrober Kies) zu unbehandelten Kontrollböden zeigten alle Varianten nur geringe Wasserverluste durch Verdunstung, die geschredderte Rinde und die Kiesauflagen bildenten den besten Verdunstungsschutz. Die geschlechtsreifen *Fraxinus*-Exemplare "Emerald" und eine 4 cm starke Auflage von Rindenmulch zeigten insgesamt das geringste negative Wasserpotential.