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LEAF AREA-LEAF MASS RELATIONSHIP IN PECAN TREES

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ABSTRACT

An experiment was carried out during the fall 1996 and 1997 to estimate leaf area, leaf mass and specific leaf area (SLA) of pecan trees. A pecan tree was cut down, harvesting its leaves, fruit and wood by quadrants in both years. Measurements of foliage density were made with the Plant Canopy Analyzer LAI-2000, LI-COR Inc. before cutting down the trees. One hundred leaves were sampled per quadrant from the first 0.6-1.0 m from the tip of branches. Another one hundred leaves were sampled from the rest of the branch's length for each quadrant, to get a total sample of eight hundred leaves per tree per year. The remaining leaves were harvested, dried and weighed to provide the leaf mass per quadrant and leaf mass for the whole tree. Leaf area and dry weight were determined at the laboratory by direct measurements of each sampled leaf per quadrant and tree. The leaf area of forty compound leaves was measured using a Delta T leaf area meter. The leaflets and the petioles of ten of the forty leaves were dissected and their area was measured by using two LI-COR leaf planimeters model LI-3000. A regression analysis was done to find leaf area-mass relationship at leaf, leaflet and branch scale.

SLA was calculated from direct measurements of leaf area and mass, as well as from non destructive measurements of leaf area made with the LAI-2000.Estimates of total leaf calculated from SLA and LAI-200 data were compared to the destructive leaf mass measurements per tree were obtained from the leaf area-mass relationships.

As expected, leaves were different in size and weight. Leaf area varied from 28.17 to 544.34 cm^2 in 1996, and from 18.52 to 324.85 cm^2, in 1997. The leaf mass had an average of 2.11 +/- 0.92 g in 1996 and 1.58 +/- 0.65 g in 1997. Leaf area and mass presented a good linear relationship. However, the slope of the line varied depending on the quadrants and leaf position. This may be the result of differences in leaf thickness caused by different light exposure. The average SLA measured directly was 92 cm^2/g for 1996 and 91 cm^2/g for 1997. The SLA estimated from light attenuation measurements (LAI-2000) was 107.27 cm^2/g for 1996, and 82.5 cm^2/g for 1997.
An equation to predict total leaf mass from indirect measurements of leaf area was obtained by averaging direct SLA estimates from the two years data:

$$T_{lm} = Tla \ / \ 9.1$$

Where: T_{lm} is total leaf mass in kilograms and Tla is the total leaf area in square meters.
The estimation error of leaf mass was 11% for 1996 and 1997. This represents a promising method to estimate the leaf mass of pecan trees

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from non destructive measurements of leaf area.

INTRODUCTION

Leaf area and leaf mass are closely related to light interception, photosynthesis, transpiration, growth rate and furthermore to yield (Ma, 1992). These parameters are important for forest and agricultural research as well for crop management practices .

Leaf area-mass relationships can be expressed by the Specific leaf area (SLA) (cm^2/g or m^2/Kg) which is the leaf area to leaf mass ratio (Reddy et al., 1989). SLA indicates leaf thickness. In addition, SLA has been related to leaf structure, growth and net photosynthesis (Barden, 1977). SLA also can be used in conjunction with leaf area to estimate leaf mass for nutrient balance calculations and growth estimates.

In most crops leaf area is defined by the leaf area index LAI. This term expresses the area of the aboveground plant components such as leaves, branches and fruit per unit area of ground in m^2/m^2 (Wells, 1990). Leaf area is usually determined directly for individual leaves using automatic leaf area meters, leaf area-leaf dimensions relations, or leaf area-weight ratios (Norman and Campbell, 1989). Although these methods require simple data, they are tedious and time consuming and involve destructive sampling. It can be practical for small crops but very hard to be used for fruit trees such as pecan.

An alternative way to measure the leaf area of a plant is the measurement of light attenuation by crops, known as a Gap Fraction Method. This method is based on the fraction of sky light attenuated by the canopy. (Wells, 1990; Wells and Norman, 1991).

Leaf mass is usually determined by simple weighting of foliage samples. However, when total mass of tree foliage is wanted, destructive sampling and weighing is impractical and prohibitive. An alternative way to define the foliage mass of trees is needed such as combining nondestructive leaf area measurements with SLA estimates.

Although several studies relating indirect and direct measurement of leaf area have been done in different crops, there is a lack of information for pecans. There is also a lack of data on SLA and the use of SLA to estimate total leaf mass from leaf area in pecan trees.

OBJECTIVES:

The objectives of this study were: to determine the SLA from destructive sampling and direct measurements of leaf area and mass in pecan trees. Determine the variability of SLA at leaflet, leaf and branch scale. Determine if leaf area measured by light interception produces SLA estimates comparable to direct measurements. Determine total leaf mass of pecan trees from leaf area measurements.

MATERIALS AND METHODS

Experiments were conducted in commercial pecan orchards during 1996 and 1997 to estimate the leaf area, leaf mass and specific leaf area. The first experiment was conducted in Berino, NM during October 1996. A 28-year-old Barton pecan tree growing on a Rincon rootstock and planted 30 by 45 feet apart from other trees was cut down and totally harvested. The second experiment was performed at San Miguel, NM cutting down and harvesting a 35-year-old Ideal variety pecan tree planted 30 by 30 feet apart. Harvesting, in both years, occurred when foliage, branches and fruit of pecan trees were at the final stage of growth.

The trees were divided in four quadrants. Each quadrant consisted of a ninety-degree section facing north, east, south and west. Before cutting down the trees, measurements of width and height by quadrants were done to obtain the profile of the trees. The central point for the profile was the center of the trunk at the soil surface.

Foliage density (leaf area, m^2/ volume of tree, m^3) measurements were also made by quadrants using a Plant Canopy Analyzer LAI-2000, LI-COR Inc. To perform the readings a ninety-degree view cap was put on the light sensor of the Plant Canopy Analyzer to limit the view of the instrument to a quadrant of the tree. The foliage density measurements with the LAI-2000 were performed using the reading procedure for isolated trees with asymmetric canopy (Li-COR, 1992). This consists of taking two readings, one above the canopy reading "A," and one below the crown and close to the trunk of an individual tree canopy, reading "B." In 1996, the above canopy readings were taken outside of the orchard where a canopy did not block the light to the plant canopy analyzer. During 1997, above readings were done on top of the canopy by using a cherry picker machine.

The cutting, sampling and harvesting of trees, as well as the area and mass determinations for both 1996 and 1997, were performed using the same methodology. Before cutting the tree, leaves, nuts and husks were collected from the ground. The cutting process was done by sawing each branch one at the time, by quadrant. The branches were cut down and their length and diameter were measured. A sample of two hundred leaves was taken randomly from each quadrant in two positions. One hundred distal leaves were collected from the first 0.60-1.0 m of each branch (outer quadrants: Qout), and one hundred leaves were harvested from the rest of the branch's length (inner quadrants: Qin). The remaining leaves in the quadrant, along with the nuts and husks were separated, saved in sacks, oven dried, and weighed. The main branch was also chopped down saving all the wood to get the total dry mass of wood per quadrant and per tree.

The 200 sampled leaves per quadrant (Qin and Qout) were taken to the laboratory to measure leaf area and dry mass. The leaf area was measured as follows: The area of forty compound leaves was measured using a Delta T leaf area meter. Ten of these forty leaves were used to determine the leaf area of individual leaflets and petioles using two leaf area planimeters model LI-3000, LI-COR, Inc. The leaflets and petiole were dissected from the leaves and run through the leaf area meters. The leaf area of remaining leaves (bulk and leftovers) was obtained from cumulative leaf area measurements with the Delta T area meter. All leaf area meters used to measure the leaf area, were calibrated to correct the leaf area of each sample. All leaves were oven dried at 65 Celsius degrees for 72 hours to obtain the dry mass. A regression analysis was done to find out if there was a relationship between leaf area and leaf mass by quadrant, leaf position and for the whole canopy of the pecan tree for each year's data.

The foliage density and canopy volume per quadrant were calculated from the field measurements by using the software support for the plant canopy analyzer C-2000-90 Version 2.14 (LI-COR, 1992). Foliage density and canopy volume were used to make an indirect estimate of mean leaf area per quadrant, and for the whole tree. Then measured leaf mass and indirect leaf area were used to calculate field estimates (indirect) of SLA. Direct SLA, was obtained for each sampled compound leaf and selected leaflets for all sampling positions by dividing the measured leaf area by the measured leaf mass.

Average SLA was obtained from direct measurements of leaf area and leaf mass made in 1996 and 1997. This average was used to estimate the total leaf mass of a pecan tree. The predicted leaf mass was compared with the whole tree's leaf mass measured in both years.

RESULTS AND DISCUSSION

Leaf area varied from 28.17 to 544.34 cm^2 in 1996, and from 18.52 to 324.85 cm^2, in 1997. The mass of compound leaves presented an average of 2.11 +/- 0.92 g in 1996, and 1.58 +/- 0.65 g in 1997. Direct measurements of leaflet area for 1996 and 1997 showed a range of 1.93 to 48.23 cm^2 with a mass range from 0.01 to 0.45 g.

A good linear relationship was found between the leaf mass and area for leaflets, compound leaves and petioles in 1996 and 1997. Figures 1 and 2, show examples of the area-mass relationships for leaves, leaflets and petioles measured in 1996. The slope of the lines in these graphs is the reciprocal of SLA. These figures show that in the same quadrants (i.e., QI) the SLA is the same for leaflet and leaves; however, the SLA of the leaflets might be different from leaves. The SLA from petioles is different from both leaves and leaflets.

Tables 1 and 2 show values of SLA measured directly in the laboratory during 1996 and 1997 respectively. The SLA estimated from direct measurements varied from 71 to 113 cm^2/g with an average of 92 cm^2/g in 1996 and varied from 72 to 108 cm^2/g with an average of 91 for 1997.

These data show no significant differences in SLA among years on leaf and leaflets. There might be a slightly significant variation in SLA within positions. Observed SLA was always higher for the medial leaves. This is consistent with the distal leaves being thicker because of receiving more sunlight.

Tables 3 and 4, show mean SLA estimates calculated from the direct and nondestructive leaf area measurements. Average SLA estimated using field measured by field measurements of light attenuation varied from 33.5 to 157.1 cm^2/g with an average of 107.27 cm^2/g for 1996 and varied from 63.0 to 132.1 cm^2/g with an average of 82.5 for 1997. Preliminary statistical analysis indicate that these differences are not statistically significant.

Total leaf mass per tree was estimated for both years using indirect leaf area measurements (table 5). The equation used to predict total leaf mass from total leaf area is:

$$T_{lm} = Tla\ / 9.1$$

where:

T_{lm} : Total leaf mass (kg)
Tla: total leaf area (m^2)

This equation underestimated total leaf mass for both 1996 and 1997 with an estimation error of 11%. This represents a promising alternative to estimate the leaf mass of pecan trees by non destructive measurements of leaf area.

CONCLUSIONS

SLA appears to be the same at leaf and leaflet scale (still being analyzed). Direct SLA and field SLA were not significantly different for both 1996 and 1997. Outside leaves may show lower direct SLA than inside leaves for 1996 and 1997 (still being analyzed). An estimate of total leaf mass per tree for 1996 and 1997 was obtained from average SLA and indirect leaf area measurements with an estimation error of 11%.

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Table 1. *Specific Leaf Area (cm^2/g) by sampling position, measured directly in 1996.*

Quadrant	*in*	*out*	*mean*
I	*88*	*80*	*84*
II	*113*	*105*	*109*
III	*91*	*71*	*81*
IV	*108*	*75*	*92*

Table 2 *Specific Leaf Area (cm^2/g) by sampling position, measured directly in 1997.*

Quadrant	*in*	*out*	*mean*
I	*103*	*73*	*88*
II	*94*	*72*	*83*
III	*120*	*88*	*104*
IV	*108*	*66*	87

Table 3. *Mean specific leaf area (cm^2/g) by method for leaf area measurements for 1996.*

Quadrant	*Leaf mass (g)*	*Direct SLA (cm^2/g)*	*Field SLA (cm^2/g)*
I	*9461.2*	*84*	*157.1*
II	*10876.3*	*109*	*82.3*
III	*10865.7*	*81*	*156.2*
IV	*33096.8*	*92*	*33.5*

***Table 4.** Mean specific leaf area (cm²/g) by method for leaf area measurements for 1997.*

Quadrant	*Leaf mass (g)*	*Direct SLA (cm^2/g)*	*Field SLA (cm^2/g)*
I	*14400*	*88*	*69.8*
II	*11500*	*83*	*65.5*
III	*13000*	*104*	*63.0*
IV	*11500*	*87*	*132.1*

***Table 5.** Estimates of total leaf mass per tree by mass equation.*

	1996		*1997*	
Mass Equation	*Mass (kg)*	*Error %*	*Mass (kg)*	*Error %*
Direct measurement	*64.29*		*50.4*	
$T_{lm} = T_{la} / 9.1$	*57*	*- 11*	*45*	*- 11*

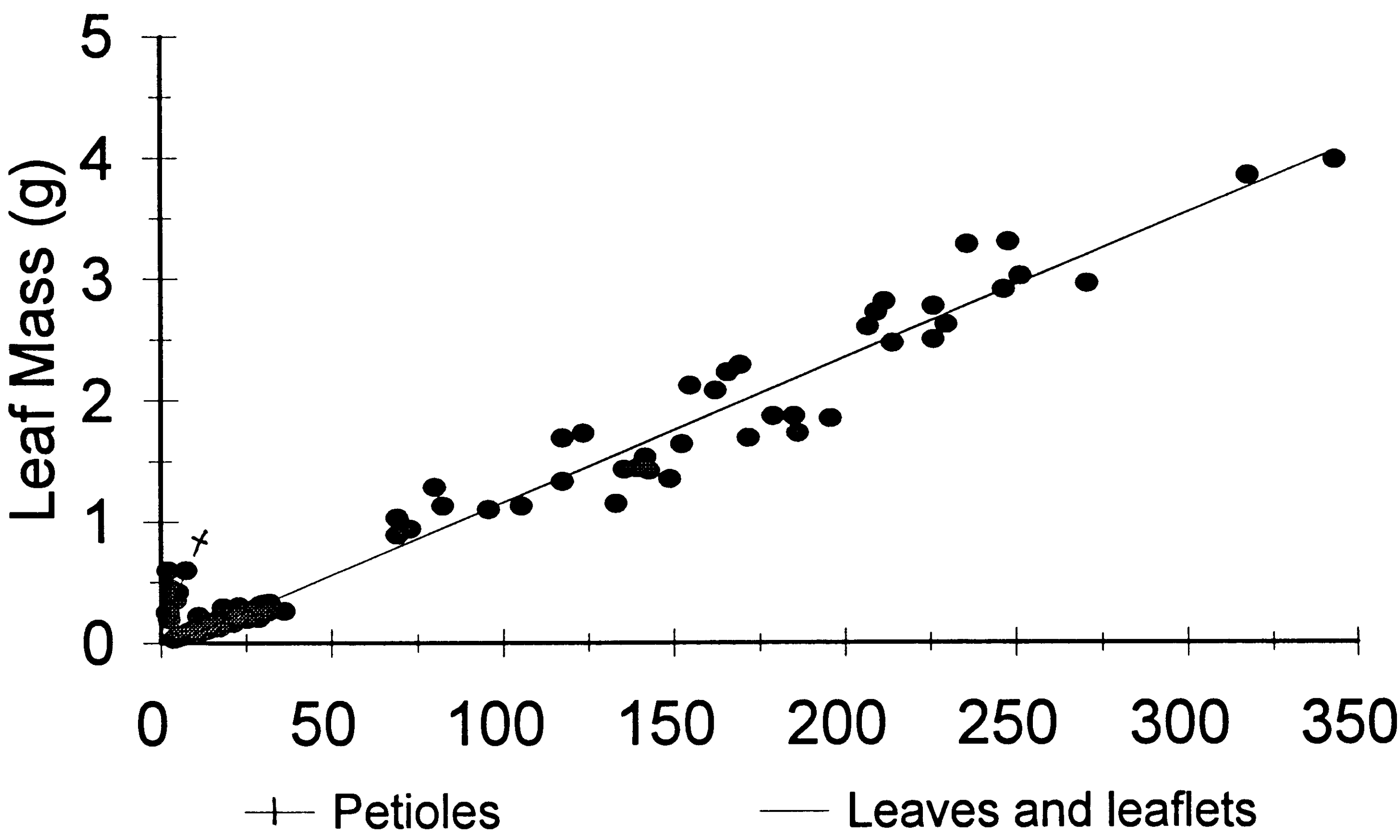

Figure 1. Plot of leaf area -mass relationships , quadrant I (in) 1996

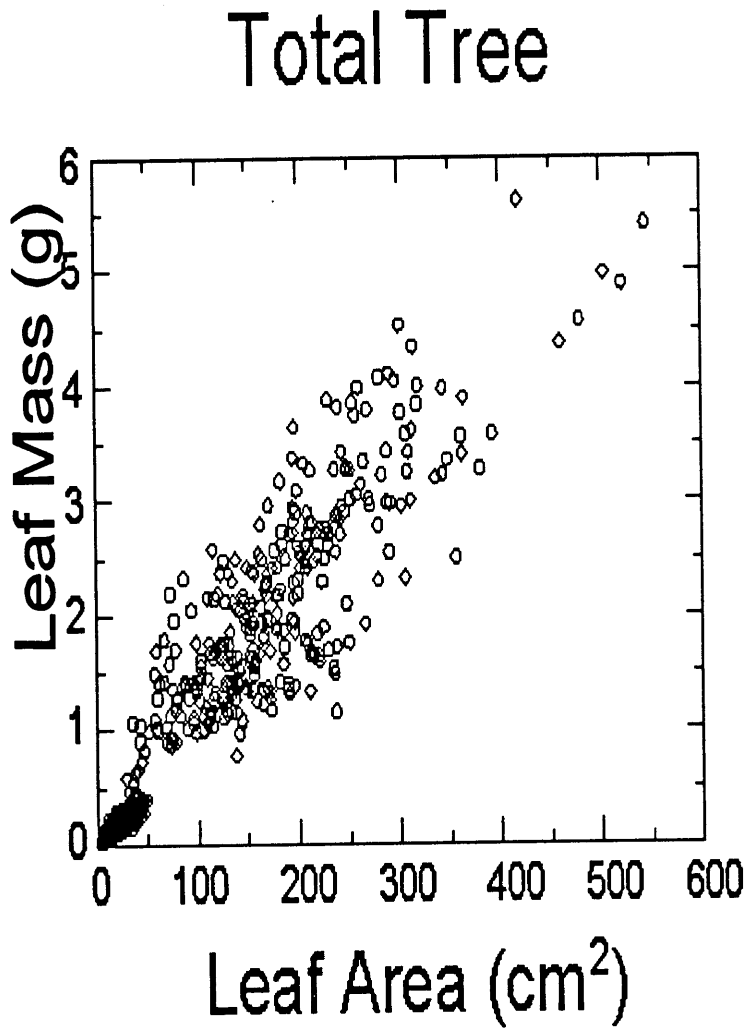

Figure 2. Plot of the area-mass relationship for leaflets and whole leaves for an entire tree sampled in 1996.