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A Quick, Easy, Accurate Method of Quantifying Vineyard Trellis Fill

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SUMMARY. Functional leaf area is the basis for vineyard productivity. Therefore, the leaf area displayed on a trellis will determine the productive potential of a vineyard. A device that uses a series of infrared sensors was constructed to quantify vineyard

trellis fill. A vertical row of sensors on a moving over-the-row vineyard trailer recorded the interception of infrared light beams through the trellis. These values were related to the total time of measurement to calculate a percentage of trellis fill. Our device was used to quantify differences among training systems applied to 'Chardonnay' grapevines. This system is quick, easy, and at least as accurate as currently used visual methods. This technique should be useful for determining the influence of various cultural practices on the development of grapevine canopies.

The photosynthetic function of leaves is the basis for grapevine productivity. Therefore, leaf area measurement quantifies a vine's potential productivity. Vine leaf area measurement has often been used to explain a vine's ability to mature a crop acceptably (Buttrose, 1966; Jackson, 1986; Kliever, 1970; Winkler, 1927; Winkler, 1958). Measuring carbon assimilation in individual leaves (Motomura, 1990) or even entire vines (Chaumont et al., 1994) is possible. However, such direct measurements of leaf function are neither feasible nor necessary to evaluate usefully the influence of various viticultural practices on vine leaf area development.

Grapevine leaf area estimates include the leaf area index (Grantz and Williams, 1993); canopy density, as measured by the point quadrat method (Smart, 1985); and trellis fill (Smart and Robinson, 1991). It has been suggested that canopy surface measurements, such as percent trellis fill, are particularly meaningful, because up to 70% of carbon assimilation by the leaf area of a grapevine occurs in the exte-

rior leaves of the vine (Grantz and Williams, 1993; Smart, 1974). Trellis fill typically has been measured by making subjective estimates, usually to the nearest 10% level (Smart and Robinson, 1991). The ability to make these estimates may vary greatly among those performing this task. Therefore, we sought to develop a technique that would require no more effort than subjective visual estimation of trellis fill, but would be objective, relatively inexpensive, and at least as accurate as visual estimation.

Methods

An over-the-row vineyard trailer (Fig. 1), which was pulled by a tractor, was constructed with an inverted U-shaped frame. Two sidewalls and a roof on this frame sheltered a 5.5-foot length of vineyard trellis. The sidewalls extended from 8 to 98 inches above the ground surface and the roof was 6 feet wide. All surfaces of this trailer were painted flat black. Fourteen infrared sensors (model 49-551A; Tandy Corp., Fort Worth, Texas) were mounted in a vertical row at 6.5-inch intervals from 8 to 94 inches above the ground surface in the middle of one of the vertical walls of the trailer (Fig. 2). A corresponding vertical row of reflectors was mounted on the opposite vertical wall. A sensor could detect an

Fig. 1. The over-the-row trailer used to measure trellis fill in a 'Chardonnay' vineyard. Vines trained mid-wire cordon (MWC) in the background and umbrella Kniffin (UK) in the foreground. Photograph taken 3 July 1996.

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Fig. 2. The over-the-row vineyard trailer with a row of infrared sensors mounted in a vertical row on the interior wall.

object in a horizontal plane whenever the object had a horizontal width of ≥ 0.5 inches. Each sensor was connected to a digital elapsed-time counter (model 10506; Syrelec Co., Bourcubus, France). A hand-operated plunger switch, located at the tractor seat, was used to begin and end a measurement period along a section of trellis. An additional digital elapsed-time counter recorded total measurement time. During a time of measurement, the duration of an interruption in the beam of light from an infrared sensor to the reflector on the opposite wall was recorded by the individual digital elapsed-time counter for that sensor. The total elapsed time and elapsed detection times of individual infrared sensors were recorded on a field data sheet. Those data were then entered into a database. A database program calculated the elapsed time of each sensor as a percentage of the total elapsed time for the observation. These percentages were summed to obtain a percentage of trellis fill for the entire vertical height of the trellis. Data were analyzed using Fisher's test for least significant difference.

The accuracy of measurements made by this device was evaluated by constructing a target zone on a grid of monofilament line in a vertical plane, which was situated equidistant between

the two vertical walls of the trailer. Five infrared sensors were used to detect objects in the target zone, which had a vertical height of 32.5 inches. A sixth infrared sensor automatically began and ended a time period of measurement for the 48-inch horizontal length of the target zone by sensing an opaque material mounted above the target zone. The trailer was pulled past this target zone at a ground speed of $\approx 1 \text{ min} \cdot \text{h}^{-1}$. Mature leaves from 'Concord' grapevines, 'Chardonnay' grapevines, and 'Bluecrop' blueberry bushes were estimated to have average areas of 38, 16, and 2 inch^2 , respectively. Circular paper targets with areas of 38 and 16 inch^2 were used to simulate the 'Concord' and 'Chardonnay' grape leaves. Rectangular pieces of paper 1×2 inches were used as targets to simulate blueberry leaves. Verification procedures included a) covering the target zone completely; b) placing large (38 inch^2), medium (16 inch^2), and small (2 inch^2) targets in the target zone so that they represented $\approx 10\%$, 25% , 50% , and 75% of the total target zone area; and c) placing vertical strips of varying

widths in the evaluated zone. Three measurements of each of three random arrangements of targets were made for each target size and percent of target zone combination.

Measurements of trellis fill were made on 4-year-old 'Chardonnay' grapevines to determine the influence of three vine-training systems on trellis fill early in the growing season. Vines were planted on a spacing of 6 feet between vines and 9 feet between rows. The three vine-training treatments measured were a) mid-wire cordon training consisting of two- to three-node fruiting spurs located on a cordon ≈ 30 inches above the ground surface; b) umbrella Kniffin training, which consisted of long canes arched over the top of the trellis so that fruiting nodes were located within the top one meter of the trellis; and c) a combination training system, which used mid-wire and umbrella Kniffin training. The overall height of the trellis was 6 feet. The experimental unit of measurement was a 24-foot long post length with four vines. Twenty-four experimental units for each training system treatment were measured before the start of growth and ≈ 7 weeks after the start of vine growth. The ground speed of the equipment was $\approx 1 \text{ min} \cdot \text{h}^{-1}$. Data were analyzed for each measurement time and for values obtained by subtracting the first time of measurement from the second.

Results and discussion

When the targets occupied $\leq 50\%$ of the target zone, measurements with all three target sizes provided estimates, which were within 10% of the area actually covered by targets (Table 1, Fig. 3). The maximum difference between actual and measured fill of the target zone for all target sizes for the 10%, 25%, and 50% zone levels of actual target zone fill was 4%, 7%, and 12%, respectively. When the target area was totally covered, the device accurately measured and estimated 100%

Table 1. The proportion of a target zone measured by the trellis fill device for combinations of three target sizes and seven percentage levels of covered area within a target zone.

Target size	Area covered (%)						
	10	11	25	50	60	68	75
Large (38 inch^2)	---	11	25	60	---	83	---
Medium (16 inch^2)	8	---	21	48	51	---	---
Small (2 inch^2)	6	---	18	48	---	---	83

Fig. 3. The percent of a target zone area actually covered by targets versus the percent of the target zone area measured by infrared sensors when three target sizes were situated within the target zone area.

fill for the target area. The largest error in predicting trellis fill occurred when as many of the large targets as possible were placed within the target zone to $\approx 75\%$ fill of the target zone. The targets actually covered 68% of the target zone, whereas measurement indicated 83% coverage, or a 15% difference. This difference is related to the inability to randomize targets. Targets were placed in orderly horizontal rows when striving to obtain 75% fill of the area. This nonrandomized arrangement led to consistent overestimation of the target zone, because the sensors were biased to consistently detect the widest portion of these circular targets. These results indicate only the limitation of this verification procedure and not the accuracy of measurement with this device. When vertical strip targets of varying widths were placed in the target zone, the infrared sensors were capable of detecting targets as narrow as 0.5 inches.

Measurements of 'Chardonnay' grapevines taken ≈ 7 weeks after the start of the growing season (Fig. 1) ranged from 34% to 60% trellis fill. At this time, the three training treatments

were significantly different from each other (Table 2). These data support field observations, which show visual differences in trellis fill among the three grapevine training systems (Fig. 1). Measurements of trellis fill for 'Chardonnay' grapevines during the dormant period were 1% to 3% (Table 2). Because the infrared sensors in this device do not detect objects < 0.5 inches wide, objects detected during the dormant period would include trunks, arms, and trellis posts, but not wires and individual fruiting canes.

When the percent trellis fill during the dormant period (Time A) was subtracted from values recorded during the growing season (Time B), the resulting trellis fill values (Time B - A) were about the same as those values obtained during the growing season (Time B) (Table 2). The low percentages of trellis fill measured during the dormant period with this instrumentation (Table 2) suggest that it is unnecessary to measure and subtract dormant period from growing season measurements to obtain meaningful trellis fill measurements.

Because a sensor can detect objects only in a horizontal plane and when the horizontal width of an object in that plane was ≥ 0.5 inches, an object may be over- or underestimated, depending on where the horizontal sensing plane intersects the object. Therefore, the accuracy of this device depends on the random arrangement of many leaf targets within each of the 6.5-inch-wide horizontal zones covered by each sensor. It is noteworthy that, even when only 10% to 11% of the target zone was occupied by targets, the difference between actual and measured fill of the target zone was $\leq 4\%$ of the total target area (Table 1). Visual estimations of trellis fill are typically made with 10% incremental estimates (Smart and Robinson, 1991). However, there is no assurance of the accuracy or consistency of such estimates. Therefore, even at low percentages of trellis fill, this device offers measurement objectivity with an accuracy that is likely to be as good or

Table 2. Trellis fill measurements of 'Chardonnay' grapevines for three training systems after dormant pruning (A), 7 weeks following budbreak (B), and the difference between these two times of measurement (B - A).

Training system	Trellis fill (%)		
	Time A	Time B	Time B - A
Mid-wire Cordon	1.4	34	33
Umbrella Kniffin	2.4	42	39
Umbrella Kniffin & Mid-wire Cordon	2.7	56	53
LSD _(0.05) ^z	0.4	2	2

^zMean separation within columns using Fisher's test for least significant difference.

better than visual estimates.

Trellis fill by itself does not adequately characterize a grapevine canopy. However, when it is combined with the point quadrat method of measuring the number of leaf layers in a canopy (Smart, 1985), objective, quantitative measurements of grapevine canopies are possible. Such measurements will often provide useful insights regarding the influence of vine manipulations on vine canopies.

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Comparing Sod Strength Parameters of Warm-season Turfgrasses Using a Hydraulically Driven Sod Strength Machine

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ADDITIONAL INDEX WORDS. sod strength, force, work, pull speed

SUMMARY. Research was conducted to evaluate the performance of a hydraulically driven turfgrass sod strength machine equipped with a force transducer to measure various strength parameters. The most commonly reported strength parameter, peak force (PF), continued to provide the quickest and easiest measurements of sod strength. Calculations of work involving the continuous measurement of sod strength over the duration of the stretch did not consistently improve the information provided by the PF measurement. Changes in sod bed pull speeds altered the calculations of work, whereas pull speed changes generally had little effect on force measurements, an important consideration for sod strength measurement devices that have limited control of

sod bed pull speed. The unit was marginally successful in distinguishing sod strength differences between St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze.] treated with various levels of pyridine herbicides. The device also provided strength parameters that distinguished the relative strengths of four warm-season turfgrass sods.

In commercial turfgrass sod production, success is achieved by rapidly growing a harvestable crop that has adequate tensile strength to facilitate handling at harvest and installation. Many machines have been designed to measure sod strength, with the most common strength measurement being the peak force required to tear a piece of harvested sod into two pieces. Rieke et al. (1968) developed the first technique in sod strength measurement by securing one end of the sod to an immobile frame and securing the other end of the sod to a movable frame that was weighted by pouring sand into an attached bucket. The weight of the sand broke the sod apart, and the weight was recorded as the force required to break the sod. Other researchers have modified Rieke's sod strength machine by installing electric motors, push-and-pull gauge scales, load sensors, and torque wrenches to measure the force required to break the sod, but all are still based on the same premise of attaching sod between an immobile and mobile frame and measuring the peak force required to tear the sod (Goatley and Schmidt, 1991; Hall et al., 1985; Jagschitz, 1980; Mitchell and Dickens, 1979; Parish, 1995; Philley et al., 1992; Troutman and Jagschitz, 1971; Turner and Dickens, 1987; Turner et al., 1990).

Burns and Futral (1980) used the Instron universal testing instrument to measure sod strength. This device offered uniform, adjustable speed, a printout of the breaking pattern, and a measurement of sod elongation before breaking; however, the Instron unit is expensive and is not designed for field use.

A hydraulically powered sod strength device was constructed at Mississippi State University, using the standard design of the stationary and mobile frames to tear a secured piece of sod into two pieces. A force transducer attached to a chart recorder was

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