use of both soil and foliar treatments.

Two significant interactions involved the source of foliar nutritional sprays (data not shown). However, yield differences between foliar treatment sources were generally $< 4\%$ (maximum $< 9\%$). Neither foliar-applied material was clearly superior, so their relative costs could be used as the selection criterion. Because no consistent difference between foliar nutritional sources was found, Mn alone must have accounted for the response, and the inclusion of other nutrients in F-2 had no effect.

This study was part of a broader project involving soil pH and Mn availability in vegetable production in the Everglades (3, 4). Whereas Lucas (7) estimated 1120 $\mathrm{kg \cdot ha^{-1}}$ of elemental S would decrease soil pH by 0.4 unit, pH decrements averaged about 0.2 unit for 1120 $\mathrm{kg \cdot ha^{-1}}$ or 0.5 unit for 2240 $\mathrm{kg \cdot ha^{-1}}$ in this study. Elemental S, either in the standard powdered or new granular formulations, generally was more effective than slag. Granular S formulations reduced pH more than powdered S, and differences between granular formulations in pH reduction sometimes occurred. Consistent with previous reports, pH appeared to decline over the course of the growing season after flooding, and flooding appeared to remove the effects of acid treatments.

Enhancing Mn availability by either soil acidification or foliar application of Mn increased celery yield. Since the effects were substitutionary, the more economical approach of foliar application, especially in conjunction with pesticide applications, is indicated. However, additional yield responses to soil treatments were observed even in the presence of foliar application. Thus, it may prove cost-effective to use soil acidification, especially with band application of elemental S and Mn combined.

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Relationships Between Leaf Area per Fruit and Fruit Quality in ‘Bing’ Sweet Cherry

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Additional index words. *Prunus avium,* linear model, quadratic model, fruit color, soluble solids, fruit weight

Abstract. **Relationships between leaf area per fruit and fruit weight, color, and soluble solids were modeled on spurs isolated following pit hardening on 2-year-old wood of ‘Bing’ sweet cherry (*Prunus avium* L.). Leaf area per fruit was found to be the largest measured source of variability in the three fruit quality parameters examined. Leaf area per fruit accounted for 66%, 36%, and 53% of the variability in fruit weight, fruit color, and soluble solids, respectively, at Pullman, Wash. Leaf area per spur accounted for 54%, 27%, and 28% of these same fruit quality parameters at Prosser, Wash. In all instances, there was a positive correlation between fruit quality and leaf area per fruit. Soluble solids content was most sensitive to increases in leaf area, followed by fruit weight and color. Leaf area per fruit is important because it represents photosynthetic potential. Ample productive leaf area is essential to producing high-quality sweet cherries.**

Horticultural commodities frequently are graded by size and/or quality, and the price paid to the grower is adjusted accordingly. Sweet cherry fruit of consistent high quality would be desirable. High-quality fruit would improve the wholesale price paid to growers and increase repeat sales at the retail level. Quality of sweet cherry fruit, however, is not easily measured. Components of quality include color, fruit size, soluble solids, firmness, and texture. Growers are paid a premium for uniformity of color and large fruit size.

Several factors have been identified that can affect the quality of sweet cherry fruit. Within-tree factors that affect fruit quality are date of anthesis, location of fruit within the canopy, and ovary diameter at initial set (4). Flowers that open early in the season produce better fruit at harvest than those that open late. Fruit on young wood are larger and have higher soluble solids at harvest than fruit from old wood.

Artificial shading of limbs for different periods during fruit development affected the quality of sweet cherries (5). Fruit on shaded limbs were slower to mature, were softer at maturity, and lower in color and soluble solids than fruit on unshaded limbs.

Facteau et al. (2) sampled limbs with different leaf to fruit ratios and found that the natural log of leaf : fruit ratios to be related linearly to fruit weight at a given color. They also found fruit firmness to be positively correlated to soluble solids and to the natural log of the leaf : fruit ratio.

Facteau et al. (1) also examined the interaction of GA and leaf : fruit ratios on fruit quality while seeking sources of variability of response to GA. They examined fruit of a standard color for weight and soluble solids and found no interaction between response to GA and leaf : fruit ratios. They found, however, leaf : fruit ratios to be additive in the model of firmness, indicating that fruit firmness was affected by leaf : fruit ratios.

Summer tipping of extension growth resulted in an increase in soluble solids when shoots were tipped during stage III of fruit development (9). This research also confirmed Patten’s work (4) that fruit at the base of 1-year-old wood were higher in soluble solids than fruit on spurs.

Spayd and coworkers (8) examined the effect of crop load on sweet cherry quality and found that cherries from heavily cropped trees (90 to 115 kg/tree) were lower in color, were softer, and had lower sugar and acid levels than cherries from lightly cropped trees on a given harvest date. This work also indicated that low leaf : fruit ratios can delay maturity.

Over a 9-year period, Proebsting and Mills (6) showed a relationship between crop load

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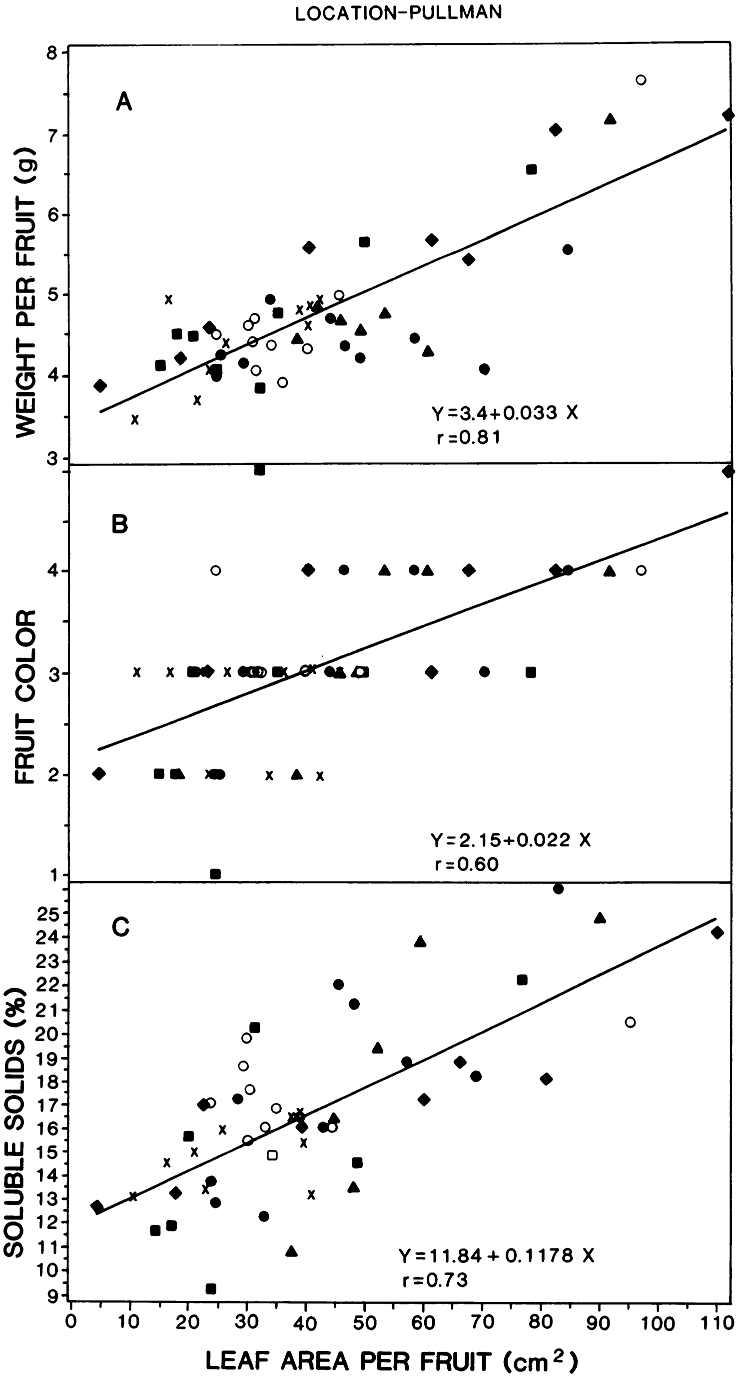

Fig. 1. Models of the relationship between leaf area per fruit and fruit quality at Pullman, Wash., 1986. (**A**) Weight per fruit. (**B**) Fruit skin color. (**C**) Soluble solids. Equations for the models are shown in each panel. See text for explanation of the fruit color index. Each symbol represents data from a different tree.

and fruit size. Heavy crop loads delayed attainment of maximum fruit size and the date of attainment of minimum acceptable color.

The research cited has indicated an apparent relationship between fruit quality and productive leaf area. Most of these studies were qualitative in nature, showing only that fruit quality was affected by changes in productive leaf area. The research described here was undertaken to examine quantitatively the relationship between fruit quality and leaf area to fruit ratios.

Experiments were performed in orchards at Pullman and Prosser, Wash. in 1986. Limbs with healthy spurs were chosen, and one spur on the distal portion of 2-year-old wood was isolated by removing a 1-cm-wide strip of bark, including the phloem, from the limb both above and below the spur (7). The xylem was left intact to allow uninterrupted flow of water and inorganic nutrients. Spurs were isolated at the beginning of stage III of fruit development. The girdles did not heal over during the experimental period. Net photosynthesis and stomatal conductance were not affected by girdling (7).

Girdles were made on at least 10 sample branches on each of six replicate trees. All spurs were harvested on one date at each site, and the spurs were brought into the lab for analysis. Fruit number, fruit weight, and leaf number were measured on each spur. Leaf area per spur was measured with a LI-COR LI-3000 area meter. Fruit color was determined on a representative fruit from each spur by comparing fruit skin color to cherry color comparators (Tech West Enterprises, Vancouver, B.C.). Fruit were assigned a number from 1 to 5, with 1 = pink, 2 = red, 3 = dark red, 4 = mahogany, and 5 = dark mahogany. Fruit soluble solids were measured with a hand-held refractometer on expressed juice.

Isolated spurs were used so the relationship between leaf area and fruit quality would be unambiguous. Carbohydrates can come only from leaves on the isolated spur in this system, and fruit are the only sinks. Spurs were chosen from acropetal portions of 2-year-old wood to eliminate variability caused by spur age (4). The 60 spurs per location gave a range of leaf areas per spur and fruit of varying quality.

Three factors were chosen as determinants of fruit quality: mean fruit weight, skin color, and soluble solids. The relationship between each quality parameter and the ratio of leaf area to fruit number was examined by analysis of covariance. Linear and quadratic equations were fitted to the data using least squares.

On isolated spurs, leaf area per fruit was the largest source of variation in fruit quality of the independent variables examined. At Pullman, leaf area per fruit accounted for 66%, 36% and 53% of the variation in fruit weight, color, and soluble solids, respectively. At Prosser, leaf area per fruit accounted for 54%, 27%, and 28% of the variation in fruit weight, color, and soluble solids, respectively.

The relationship between fruit weight and leaf area per fruit was described best by a linear function at both Pullman and Prosser (Figs. 1A and 2A). The equations for the functions are given in the figure panels. At Pullman, an increase of 1 g in fruit weight is predicted to require an additional 30 cm^2 of productive leaf area; at Prosser, an additional 32 cm^2 of leaf area would be required.

Fruit color was described best by a linear function at Pullman (Fig. 1B). At Prosser, the best-fit equation was quadratic (Fig. 2B). Increasing fruit color one grade would require an additional 45 cm^2 of leaf area at Pullman. In the linear portion of the function at Prosser, only an additional 20 cm^2 would be required to increase fruit color one grade. The fruit color data were discreet, so data points are not scattered within the plots.

The relationship between soluble solids and leaf area per fruit was linear at Pullman (Fig. 1C), but was quadratic at Prosser (Fig. 2C). Function equations are shown in the figure panels. An increase of 8.5 cm^2 was required at Pullman to increase soluble solids levels by 1%; at Prosser, 7.5 cm^2 was required in the linear portion of the curve.

In all instances, there was a positive correlation between fruit quality and leaf area per fruit. Leaf area per fruit, of course, is not important itself, but it represents potential photosynthetic productivity. Photosyn-

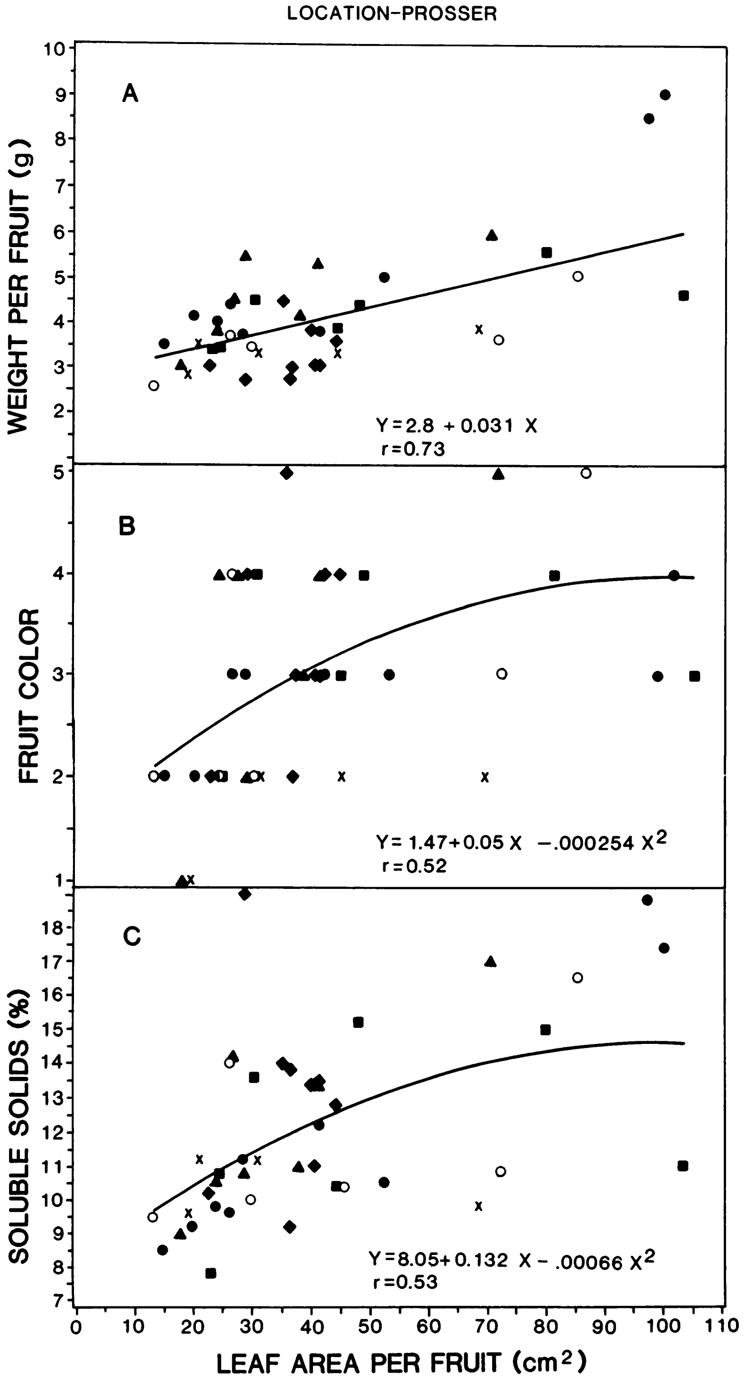

Fig. 2. Models of the relationship between leaf area per fruit and fruit quality at Prosser, Wash., 1986. (**A**) Weight per fruit. (**B**) Fruit skin color. (**C**) Soluble solids. Equations for the models are shown in each panel. See text for explanation of the fruit color index. Each symbol represents data from a different tree.

thetic productivity is apparently important to fruit quality. These models indicate that increased total photosynthesis on a spur basis, and presumably increased photosynthate availability to the fruit, increased fruit quality.

The relationship between leaf area and fruit size and sugar content shown here is similar to that shown for apples (3), peaches (10), and grapes (11). These early studies are, however, difficult to interpret because multiple sinks may have been present on the girdled limbs. It was difficult also to account for differences in translocation efficiency from the various leaves on the limbs.

Functions that were linear over the range of leaf area : fruit ratios studied here eventually would level off, giving no increase in fruit quality with increasing leaf area per fruit. This same phenomenon has been observed in peaches (10). When saturation of these fruit quality parameters occurs, fruit quality presumably is limited by internal factors, which are not affected by the supply of photosynthate. This aspect is illustrated by the quadratic functions in some models. Care also must be taken not to extrapolate the results to greater leaf area : fruit ratios than were examined here.

One explanation for the saturation of fruit quality at low leaf area : fruit ratios at Prosser is that the fruit was harvested at a less-mature stage than at Pullman. Had the fruit been allowed to remain on the tree longer, the point of quality saturation may have been increased and perhaps the functions would have been linear over the range of leaf area to fruit ratios studied. Alternatively, spur leaves have been shown to lack capacity to support entirely the growth of sweet cherry fruit on a spur (7). Thus, fruit quality would be expected to be lower on isolated spurs.

The lines do not intercept the origin at 0 leaf area, because the girdles were not made until the beginning of stage III of fruit development. Prior to this time, about 30% of fruit dry matter already had accumulated, and fruit size may already have been affected (4). The remaining variability in fruit size was almost totally explained by the leaf area to fruit ratios. Carbohydrate accumulated prior to girdling may have come from leaves at other locations in the canopy or from stored reserves (7).

Increasing leaf area : fruit ratios and thus fruit quality cannot be accomplished economically through thinning, since no chemical thinning agents are currently available for sweet cherry. Obtaining and retaining as much productive, well-lighted leaf area in trees as possible would appear prudent. This research indicates that there is a positive correlation between leaf area per fruit and fruit quality. Fruit quality can saturate with regards to leaf area. Ample productive leaf area is essential to producing high-quality sweet cherries.

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Influence of Aeration, Topdressing, and Vertical Mowing on Overseeded Bermudagrass Putting Green Turf

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Additional index words. cultivation, transition, warm-season, cool-season, *Lolium perenne, Cynodon dactylon* X *C. transvaalensis*, perennial ryegrass

Abstract. **Field studies were conducted for 4 years on putting green turf to determine the influence of cultivation practices on the transition from overseeded perennial ryegrass (*Lolium perenne* L. 'Yorktown II') turf to hybrid burmudagrass [*Cynodon dactylon*(L.)Pers. X *C. transvaalensis* Burtt-Davies] in the spring. The cultivation practices of core aeration, vertical mowing, and topdressing were shown to have no positive influence of increasing the rate of bermudagrass coverage during the spring on bermudagrass greens overseeded with perennial ryegrass. The verticut treatment resulted in decreased bermudagrass coverage as well as a reduction in turf quality. All cultivation practices resulted in some quality loss at various times during the spring transition period compared to the control.**

Bermudagrass putting greens in the southeastern United States are overseeded to provide green color and uniform surfaces, to prevent attrition damage from equipment and foot traffic, and to minimize the disruptive invasion of weeds during winter dormancy. Greens normally are overseeded with cool-season grasses in the fall several weeks prior to frost. The spring transition period from cool-season to warm-season grasses is particularly troublesome. Competition from cool-season grasses has been reported to delay emergence of bermudagrass in the spring (1, 6). A substantial loss in turfgrass quality results when there is a rapid decline in cool-season grasses and delayed emergence of bermudagrass. Several cultural practices have been reported to hasten or delay spring transition (2, 4, 5). It has been reported that vertical mowing in two directions weekly and core aeration improve the conditions for bermudagrass emergence (2). Recent studies have indicated that high-intensity vertical mowing slowed bermudagrass emergence (3). The development of drought- and disease-tolerant cool-season turfgrasses for overseeding has magnified the problems with spring transition.

The objective of these studies was to determine the effect of core aeration, vertical mowing, or topdressing on the rate of bermudagrass emergence and quality of putting green turf during the spring transition.

Four separate experiments were conducted during 1983–1986 on a hybrid 'Tifgreen' bermudagrass green overseeded with 'Yorktown II' perennial ryegrass. The putting surface was verticut in two directions 1 week prior to overseeding. Vertical mower blades 1 mm thick were spaced 1.27 cm apart and set to penetrate the soil surface to 2 mm. The green was overseeded the first week in October with ryegrass and topdressed with a washed sand at the rates of 1250 and 18,123.78 $kg \cdot ha^{-1}$, respectively. The particle distribution of sand was 0.1% (<0.05 mm), 0.4% (0.05–0.1mm), 19.2% (0.1–0.25 mm), 51.2% (0.25–0.5 mm), 21.7% (0.5–1 mm), 5.9% (1–2 mm), and 1.4% (2–4.7 mm). The cultivation treatments were initiated the first week in April each year on a uniformly dense stand of perennial ryegrass. The vertical mowing treatment was applied weekly for 10 weeks in two directions. Vertical mower blades were spaced 1.9 cm apart and set to penetrate the soil surface to 2 mm. Core aeration was applied only at the initial date with 1.27-cm-diameter tines on a Ryan Greensaire. A washed sand topdressing was applied weekly for 10 weeks with a centrifugal-type fertilizer spreader at a rate of 13.2 $kg \cdot ha^{-1}$.

The green was constructed of 60 sand : 30 pine bark medium (v/v). The particle distribution of sand was 3% (<0.05 mm), 1%

Table 1. The percentage of bermudagrass after cultivation treatment on a bermudagrass green overseeded with perennial ryegrass.

Treatment and year	Bermudagrass (%)					
1983	*29 Apr.*	*12 May*	*27 June*	*14 July*		
Topdressing	36.2	60.0	66.2	90.0		
Aeration	60.0	53.8	75.5	91.8		
Control	52.5	58.8	75.0	96.5		
Verticut	55.0	48.8	69.2	80.5		
LSD$_{0.05}^{z}$	13.5	4.7	8.5	12.5		
1984	*28 May*	*21 June*	*6 July*			
Topdressing	26.2	86.2	97.5			
Aeration	23.8	95.0	96.0			
Control	26.2	94.2	95.0			
Verticut	13.8	76.0	86.0			
LSD$_{0.05}$	11.6	5.2	4.5			
1985	*26 Apr.*	*10 May*	*21 May*	*3 June*		
Topdressing	25.0	26.2	70.0	93.8		
Aeration	23.8	37.5	66.2	93.8		
Control	25.0	25.0	75.0	92.5		
Verticut	25.0	25.0	58.8	92.5		
LSD$_{0.05}$	10.0	2.8	8.0	4.8		
1986	*5 May*	*12 May*	*20 May*	*26 May*	*2 June*	*10 June*
Topdressing	20.0	41.2	37.5	40.0	68.8	85.0
Aeration	17.5	36.2	36.2	35.0	77.5	87.5
Control	21.2	36.2	40.0	33.8	65.0	86.2
Verticut	10.0	21.2	16.2	15.0	45.0	43.8
LSD$_{0.05}$	6.3	6.8	7.5	9.4	7.3	7.2

[z]Mean separation within columns by LSD, 5% level.

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