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Water Relations and Yields of Three Rabbiteye Blueberry Cultivars with and without Drip Irrigation[1]

P. C. Andersen, D. W. Buchanan, and L. G. Albrigo[2]
Fruit Crops Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611

Additional index words. blueberry, irrigation, epicuticular, wax, SEM

Abstract. **Drip irrigation applied to cultivars of rabbiteye blueberry (*Vaccinium ashei* Reade) maintained soil moisture at 25 to 35%, (volume basis), –0.07 bars soil-water potential while no irrigation resulted in 12.5% soil moisture, –2 to –3 bars. Irrigation reduced leaf diffusive resistance (r_L) by 50% and increased transpiration (T) by 70% but had no significant effect on midday stem xylem pressure potentials (Ψ_x). Both yield and berry weight from irrigated plots were increased from 20 to 25% over those on nonirrigated plots. Seasonal changes in Ψ_x, r_L, and T of nonirrigated bushes suggested this species has some characteristic adaptations to drought conditions, one such adaptation being wax rodlets observed in and adjacent to stomatal pores. These may have contributed to a favorable water balance under stress by increasing leaf diffusive resistance.**

Rabbiteye blueberry bushes are shallow rooted yet capable of surviving substantial drought periods (9). Yearly precipitation in Florida is 140 cm but seasonal distribution is not suitable for highest yields, since rabbiteye blueberries develop from March to June, the usual dry season in north Florida.

Irrigation is an important means of increasing crop productivity (5, 11, 15, 19, 20, 24, 26, 28). Prior work demonstrating the benefits of irrigation on rabbiteye blueberries has not been found. The objective of this study was to determine if drip irrigation would increase yield and fruit size enough to be of value to commercial blueberry growers. Plant moisture status was monitored as were environmental variables in order to relate yield data with water stress.

Materials and Methods

The experimental site was a 0.8 ha planting of 5-year-old rabbiteye blueberries at the IFAS Horticultural Unit 12 km northwest of Gainesville Florida. The soil was Kanapaha fine sand with pine bark mulch and a clay hardpan at 25 to 35 cm depth. 'Woodard', 'Bluegem', and 'Tifblue' plants were spaced 2 m within and 4 m between rows. Zero, 10.8 (a dripper) and 21.6 (2 drippers) liters per day per bush were applied through a drip irrigation system.

Yield, berry weight and percentage total soluble solids were measured on 108 plants. The experimental design was randomized block with 4 bush plots and 3 replications per cultivar.

Soil moisture was monitored weekly at a depth of 20 cm with a Troxler neutron probe meter from bloom in March to the

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[2]University of Florida, Institute of Food and Agricultural Sciences, Agricultural Research and Education Center, P.O. Box 1088, Lake Alfred, FL 33850.

last harvest in July. Calibration data of Bartholic and Buchanan (3) were used to convert readings to % soil moisture.

Ψ_x and r_L were measured with a Scholander pressure chamber and a diffusion porometer, respectively, between 12:00 and 3:00 PM on samples obtained from the 21.6 liters per day on irrigated and nonirrigated plots. Two to 3 sun exposed terminal leafy branches excised from 6 comparable plants per treatment were placed in an airtight chamber for Ψ_x determinations (2, 4, 6, 10, 14, 23, 25, 28). Three to 4 sun-exposed leaves for 6 plants per treatment were measured for r_L. Calibration curves for r_L were compiled at 2.5°C intervals from 20 to 40°; r_L and values of T per unit leaf area were calculated according to methods of Kanemasu et al. (17) and van Bavel et al. (31).

'Woodard' and 'Bluegem' berries were picked with a hand-held mechanical harvester on June 12 and June 15-16 and 'Tifblue' on June 21-22 and July 11-12, placed in the shade and weighed within 2 hr. Random samples of mature berries were counted and weighed for each harvest. Percentage soluble solids (°Brix) of screened juice was determined by refractometer .

Both leaves and berries were examined with the scanning electron microscopy (SEM). Samples were prepared and air dried according to Albrigo's (1) procedures. Leaf and berry skin sections were mounted on metal stubs with silver glue and sputter coated with a 100 Å film of gold palladium (60-40) prior to viewing. Stubs were viewed on a JEOL JSM 35 SEM operated at 15 Kv and 100 μA current.

Results and Discussion

Fruit yield and quality. The combined irrigation treatments increased yields 9 to 31% over the nonirrigated control. Two drippers did not increase yields significantly over 1 dripper per bush (Table 1). Drip irrigation significantly increased yields of only 'Bluegem' and 'Tifblue', 25 and 31%, respectively, but did not significantly increase yield of 'Woodard'. 'Tifblue', with the largest fruit load showed the largest yield increase with irrigation.

Berry weights were increased about 20% with drip irrigation (Table 1). Thus, yield increases were due primarily to increased berry size. When all cultivars were combined 2 drippers significantly increased berry weight over 1 dripper per bush which in turn was significantly greater than the control.

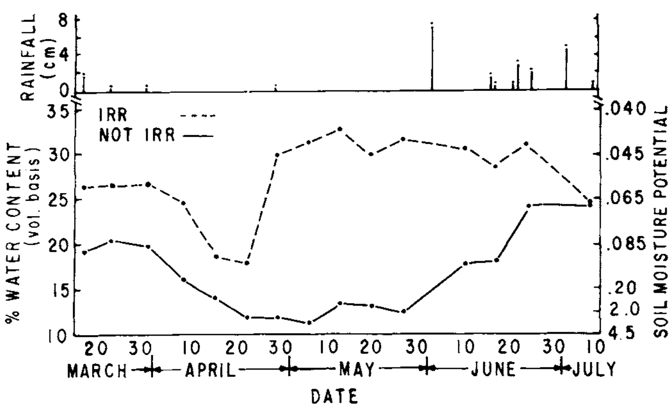

Fig. 1. Soil water (%) and precipitation from March 15 to July 10, 1977, of drip irrigated and nonirrigated rabbiteye blueberry plots, Gainesville, Fla., 1977. Soil water potential values were previously determined for this soil (3).

Berry weight but not yield was increased significantly by 2 drippers over 1 dripper per bush, probably because of inherent variability in fruit set and initial bush size. The discrepancy between irrigation significantly increasing berry weight but not yield of 'Woodard' may have resulted from variability in fruit set.

A large fruit set due to favorable winter chilling and late winter precipitation may have accentuated effects of spring drought on berry wt. Nonirrigated rabbiteye bushes were subjected to 12.5% soil moisture (–2 to –3 bars soil moisture potential) throughout most of the berry maturation period as a result of only 1.2 cm precipitation in April and May (Fig. 1). The lowest soil moisture potential recorded on irrigated plots was –0.1 bar but even this was near field capacity (17% by volume).

Percentage total soluble solids were reduced 10% on irrigated bushes (Table 1), the decrease being primarily a dilution effect corresponding to increased berry weight. Irrigation alone decreased total soluble solids 9 or 10% but increased berry weight 15 to 22%, hence there may have been a benefit of irrigation on total photosynthesis (Pn). This possible response

Table 1. Effect of 3 irrigation levels on yield and berry quality of 'Tifblue', 'Bluegem', and 'Woodard' blueberry, Gainesville, Fla., 1977.

Cultivar	Avg yield per plant (kg)	Increase in yield (%)	Avg berry wt (g)	Berry wt increase (%)	Percent soluble solids (°Brix)	Decrease in soluble solids (%)
Tifblue						
No irrigation (control)	9.0a[z]	--	1.08a	--	15.0a	--
1 dripper/bush	11.8b	31	1.30b	21	14.3b	4.6
2 drippers/bush	11.8b	31	1.35b	25	14.0b	6.9
Bluegem						
No irrigation (control)	5.3a	--	1.33a	--	15.1a	--
1 dripper/bush	6.0ab	15	1.42ab	7	13.1b	13.2
2 drippers/bush	7.0b	34	1.54b	14	12.6b	16.7
Woodard						
No irrigation (control)	5.0a	--	1.08a	--	15.0a	--
1 dripper/bush	5.6a	11	1.30b	20	14.0b	7.3
2 drippers/bush	5.4a	7	1.40b	28	14.0b	8.3
All Cultivars						
No irrigation (control)	6.4a	--	1.16a	--	15.0a	--
1 dripper/bush	7.8b	21	1.33b	15	13.7b	8.8
2 drippers/bush	8.0b	25	1.42c	22	13.5b	10.3

[z]Mean separation by Duncan's multiple range test, 5% level.

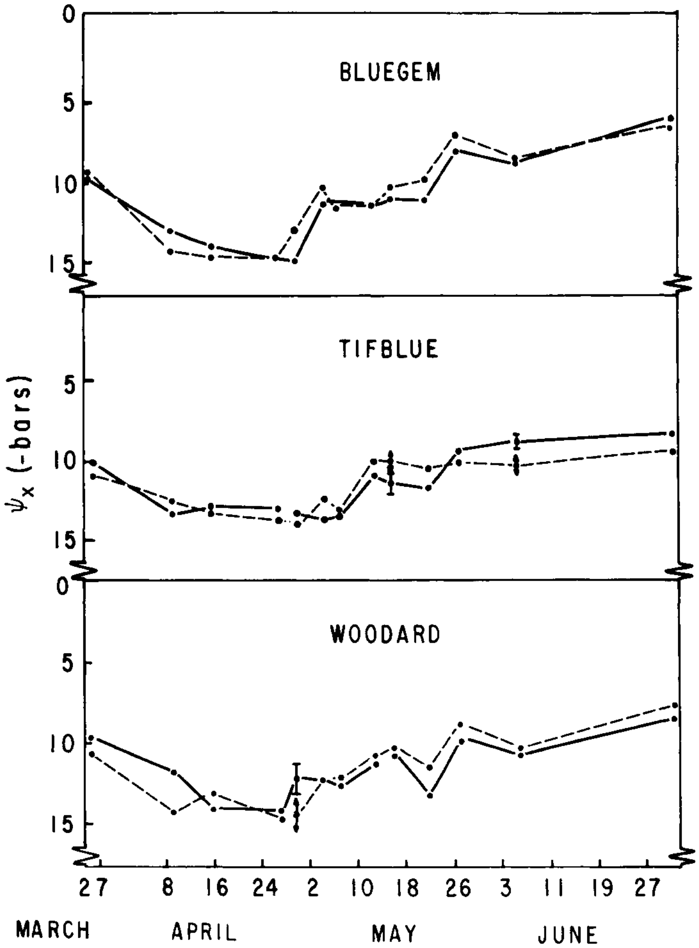

Fig. 2. Midday minimum terminal stem unit xylem pressure potentials (ψ_x) for irrigated and nonirrigated plants of 3 rabbiteye blueberry cultivars, Gainesville, Fla., 1977. Dashed lines irrigated; solid lines not irrigated. Vertical bars are SD.

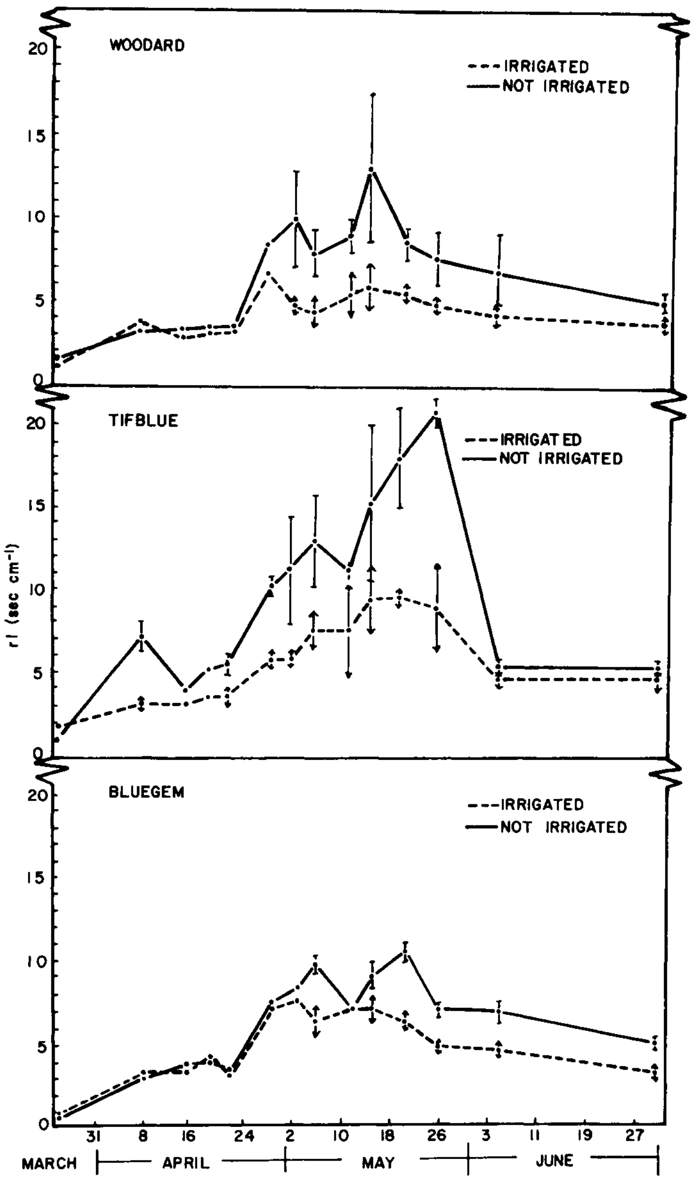

Fig. 3. Midday leaf diffusive resistance (r_l) for irrigated and nonirrigated plants of 3 rabbiteye blueberry cultivars, Gainesville, Fla., 1977. Dashed line irrigated; solid line not irrigated. Vertical bars are SD.

will have to be examined more carefully in the future with experiments which include determinations of the quantity of soluble solids per fruit and per bush.

Plant water relations. Midday ψ_x levels apparently were not affected by the 2 to 3 bar soil moisture potential differential between irrigated and nonirrigated treatments (Fig. 2). A seasonal change in midday ψ_x, which occurred for both treatments after May 1, also was not related to any change in soil moisture and may have been due to a change in evaporative demand. The berry weight increase and dilution of soluble solids of fruit on the irrigated bushes indicated these bushes experienced a more favorable internal water status and less stress even though midday ψ_x values of irrigated and nonirrigated bushes were similar.

Midday r_L values in late March, before leaves were fully expanded, were 1 sec cm^{-1} (Fig. 3); r_L values of 3 sec cm^{-1} were recorded in early April after leaf expansion. Physiological changes with aging or a greater stomatal density on partially expanded leaves may explain the trend (18).

Significant differences in r_L between irrigated and control treatments were apparent in May at a time when control treatments were experiencing -2 to -3 bars of soil moisture potential (Fig. 1 and 3). Nonirrigated control r_L often ranged between 10 to 20 sec cm^{-1} during May, approximately double the values of irrigated bushes and this relationship was maintained throughout the latter stages of berry maturation.

Irrigated 'Tifblue' and nonirrigated 'Bluegem' had similar r_L (Fig. 3). 'Tifblue', with and without irrigation, exhibited the highest r_L values which may have resulted from the higher yield of this cultivar (Table 1).

Estimated T was increased 70% in May with drip irrigation (Fig. 4). The T of 'Tifblue' with or without irrigation was 2/3 that of 'Woodard' or 'Bluegem'. Measurements of average area/leaf were 10.3, 11.1, and 7.7 cm^2 for 'Woodard', 'Bluegem', and 'Tifblue', respectively, Cultivar differences in leaf area further increased leaf T differences among cultivars. Thus an average leaf of 'Tifblue' transpired half as much water as those of the other 2 cultivars during midday hours. Bushes of each cultivar have distinct shapes and branching characteristics. 'Woodard' bushes are smallest in stature. Total water use per bush differences, between 'Tifblue' and 'Woodard' plants, would therefore not be as great as their T rates.

Adaptations to water stress. All rabbiteye cultivars maintained relatively similar midday ψ_x independent of up to -2

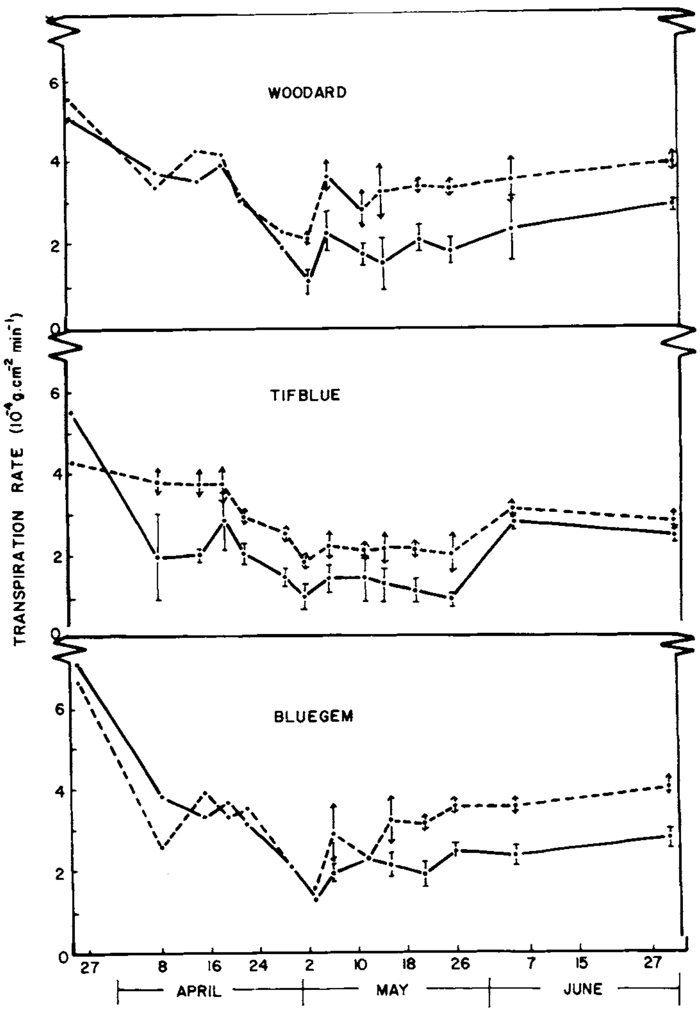

Fig. 4. Midday maximum calculated leaf transpiration rates (T) for irrigated and nonirrigated plants of 3 rabbiteye blueberry cultivars, Gainesville, FL, 1977. Dashed line irrigated; solid line not irrigated. Vertical bars are SD.

to −3 bars soil water potential difference between treatments (Figs. 1 and 2). Solar radiation and leaf temperature remained high and dew point low; therefore, conditions of high evaporative demand existed throughout the spring. Irrigated and nonirrigated bushes displayed similar ψ_x but different r_L values (Figs. 2 and 3). Typically, stomatal closure is reported to occur when a critical ψ_x is approached preventing further decline in ψ_x (6, 8, 21, 27, 30). The ψ_x at which stomatal closure occurs is species and environment dependent (6, 21, 30). Carr et al. (6), working with tea plants, and Unterscheutz et al. (30), with Douglas-fir seedlings, demonstrated previously water stressed plants close stomata at higher ψ_x than previously unstressed plants. Similarly, a stomatal adaptation to drought may have occurred with blueberry plants receiving no significant rainfall or irrigation for 2 months.

Two plant charactersitics determine a plant's moisture status, efficiency of the water uptake and transport system and regulation of water loss (7). ψ_x decreased slightly, T remained stable but r_L increased dramatically during the 2 month period of high evaporative demand and no precipitation (Figs. 1-4). Effective regulation of water loss as reflected in the r_L values, was utilized in this species to maintain a favorable water balance. Midday r_L values of 5 sec cm^{-1} for irrigated 'Woodard' and 'Bluegem' were close to minimum values reported for mesophytes (8). This is not consistent with the view that increased midday stomatal closure is responsible for the seasonal increase in midday ψ_x (8, 27, 30). Diurnal or seasonal variations in osmotic potential of the vacuole determine ψ_x minima and changes in osmotic potential may explain the trend (22, 23, 29).

The progressive seasonal increase in ψ_x probably did facilitate berry growth by cell expansion (13). Final berry swell begins 16 to 26 days prior to berry maturation and demands for water and the need to maintain high turgor are greater during this period (9, 32).

Scanning electron micrographs of nonirrigated plant leaf surfaces indicated wax rodlets covered the entire leaf surface (Fig. 5A-D). Individual rodlets are branched and adjacent rodlets appeared interconnected (Fig. 5B, D). Abundant wax rodlets occurred both in and around stomatal pores (Fig. 5B, C). Freeman et al. (12) determined the leaf epicuticular wax density (μg/cm^{-1}2) on leaves of nonirrigated 'Bluegem' increased during the 1977 season until May 14 and then decreased through measurements ending in August. Wax buildup and decline corresponded with an increase and decline in rodlet structures over the whole surface including the stomatal antechambers. These changes in concentration of epicuticular wax were correlated with r_L of 'Bluegem' in this study, r = 0.95 (P = 1%), and inversely correlated with T, r = −0.84 (P = 5%). This suggests epicuticular wax, particularly that within and surrounding the stomatal pores, may influence r_L of nonirrigated rabbiteye bushes. However, the degree to which it contributes was not directly assessed, since stomatal antechamber resistance is only one of several resistances contributing to overall leaf resistance (8). Rentschler (21) determined leaf T was directly related to the extensiveness of leaf surface wax for numerous plant species. Jeffree et al. (16) estimated a 2/3 reduction in T and a 1/3 reduction in Pn is provided by wax in the stomatal antechambers of Sitka spruce. Turrell (29) has described a partial resinous occlusion in stomatal pores of citrus; however, there appear to be no prior reports of wax rodlets occurring in the stomatal antechamber of a woody angiosperm.

'Tifblue' yielded substantially more fruit of comparable quality to the other cultivars. This was accomplished without a noticeable difference in ψ_x. Thus it is possible that 'Tifblue' is a more efficient cultivar from the standpoint of water use.

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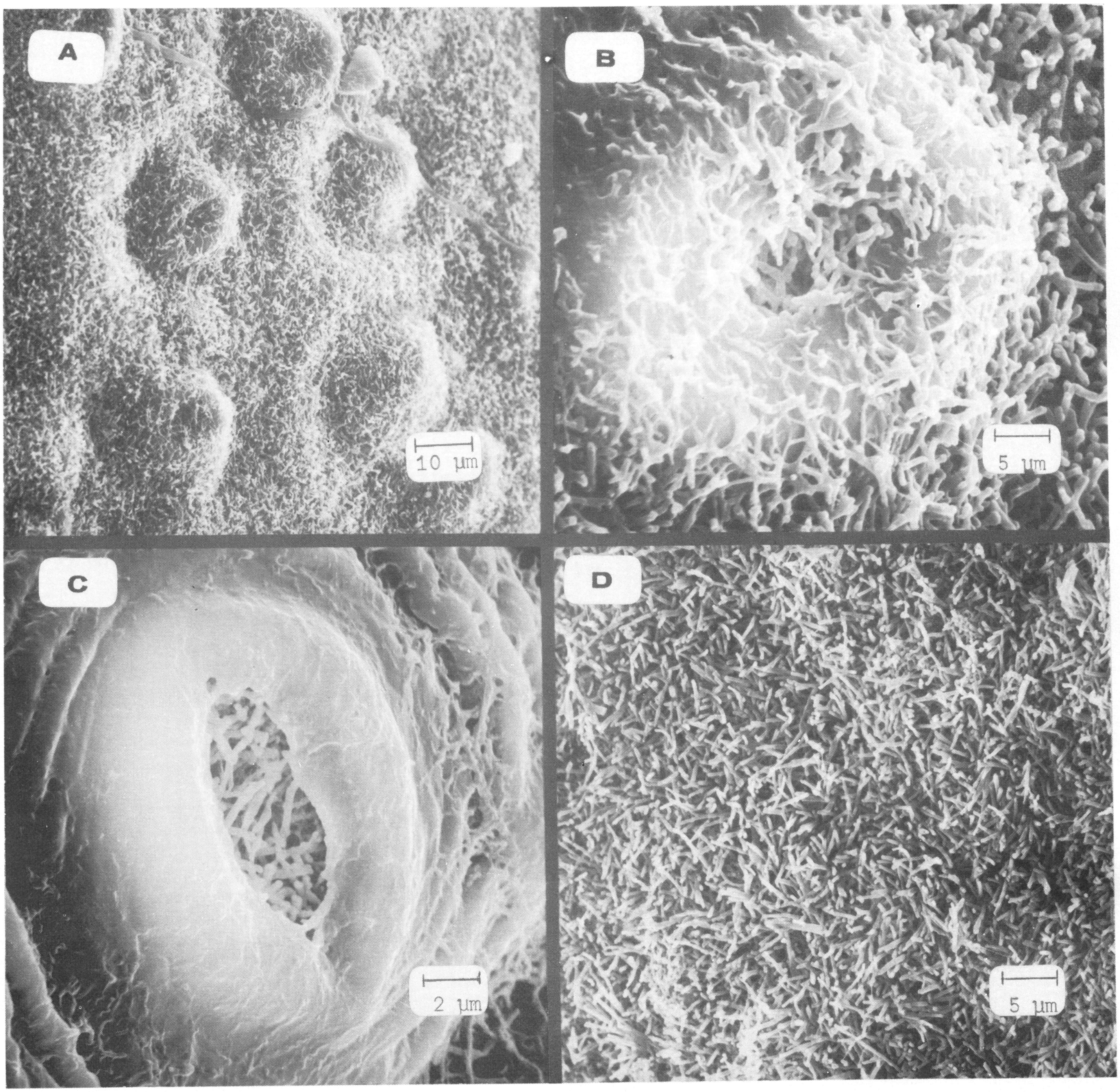

Fig. 5. Scanning electron photomicrographs of air dried abaxial leaf surfaces showing wax rodlet structure over entire surface (A) and in and over the stomatal antechambers (B & C), and branching of (D).

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Effect of Selected Dormant Pruning Techniques in a Hedgerow Apple Orchard[1]

D. C. Ferree
Department of Horticulture, Ohio Agricultural Research and Development Center, Wooster, OH 44691
A. N. Lakso
Department of Pomology and Viticulture, New York State Agricultural Experiment Station, Geneva, NY 14456

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Abstract. **Three hand pruning systems (annual, biennial, and triennial) and 2 combinations of mechanical hedging and hand pruning were compared on 6 cultivars of apple (*Malus domestica* Borkh.) on Malling (M) 26 planted in 1968 at a spacing of 3.6 × 6 m. In general cultivars responded similarly to the pruning treatments. After 6 years the pruning treatments had no apparent influence on trunk circumference and tree height, but hedging decreased tree spread. There were similar light levels with all pruning treatments. Inserting limb spreaders and pruning annually had the highest labor requirements and was among the better treatments in inducing larger fruit size, accumulated yield/tree, yield/trunk cross sectional area and revenue/tree. Hedging plus biennial pruning had a smaller labor requirement and was equivalent to annual pruning in fruit size, accumulated yield/tree, yield/trunk cross sectional area and revenue/tree. Hedging followed by annual pruning resulted in the lowest number of fruit/tree, accumulated yield/tree and yield/trunk cross section and was considered the least desirable treatment.**

Early studies indicated that pruning reduced tree size and total yield (4, 5), but tended to increase fruit size and improve fruit color of apples (6). The degree of improvement in size and color varied with cultivar and was not always enough to produce an economic benefit (6, 17). Recent studies indicated that the combination of pruning, training, and brush removal was the second most costly preharvest operation in apple production (14, 20). In order to lessen the cost and labor burden of pruning, various approaches have been studied. Heinicke (11, 12) suggested that training trees to a central leader utilizing limb spreaders and annual pruning would result in high quality fruit and efficient labor utilization. Other investigators (1, 3, 8, 9, 10) attempted to mechanize a portion of the pruning operation utilizing either hedging or slotting saws. Although these techniques resulted in a 20-30% reduction in pruning labor, cultivars responded quite differently (8), and fruit color and size were decreased unless adequate hand pruning followed mechanical pruning. Duggan (5) and Preston (18) found that biennial rather than annual pruning was sufficient with 'Cox's Orange Pippin' to maintain fruit size and quality.

The costly nature of pruning and the need to maintain adequate fruit size and color on a range of cultivars prompted this study to 5 pruning techniques on 6 cultivars designed to reduce pruning time and maintain yield and quality.

Materials and Methods

Trees of 'Blaxtayman', 'Gallia Beauty', 'Golden Delicious', 'Jonathan', 'Melrose', and 'Red Prince Delicious' on M 26 were planted at a spacing of 3.66 × 6.10 m in 1968 at the Ohio Agricultural Research and Development Center in Wooster. The trees supported by individual posts were trained as central

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