Palmette-leader and Central-leader Tree Forms Compared for Light Distribution, Productivity, and Fruit Quality of 'McIntosh' Apple Trees

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Abstract. Mature 'Macspur McIntosh'/MM.106 apple trees (*Malus domestica* Borkh.) trained to the central-leader (CL) tree form were converted to the palmette-leader (PL) tree form in 1987 by removal of east- and west-oriented scaffolds in the upper canopy. Control trees were pruned to maintain the CL form. Dormant pruning in subsequent seasons maintained either tree form. No summer pruning was done. Canopy light levels along horizontal transects 1 m above the soil and vertical transects, both through the center of the canopy, were unaffected by tree form or transect direction. Yields were significantly lower for PL trees in 1987 and 1989, while yield efficiency was reduced in PL trees in all 3 years. Fruit size, trunk cross-sectional area growth, and foliar macronutrient content were unaffected by tree form. Fruit color development in both the upper and lower halves of the canopy was not influenced by tree form during the study.

'McIntosh' apples frequently fail to develop sufficient red skin color for fresh-market standards when fruit reach harvest maturity. This problem has been addressed by the use of growth regulators (Edgerton and Blanpied, 1970; Forshey, 1970; Greene et al., 1977; Looney, 1971, 1975) and summer pruning (Autio and Greene, 1990; Lord and Greene, 1982; Lord et al., 1979). Recently, the palmette-leader (PL) tree form has been proposed as a means to improve light-penetration into the canopies of mature apple trees and to increase yields (Lakso et al., 1989; Robinson and Lakso, 1986). Lakso et al. (1989) studied the PL tree form in widely spaced, annually summer-pruned 'McIntosh' trees. The trial described here was established to compare canopy light penetration, yield, fruit size, and fruit color development of the PL tree form with the conventional central-leader (CL) tree form in nonsummer-pruned 'McIntosh' apple trees somewhat larger and more closely spaced than those used by Lakso et al. (1989).

'Macspur McIntosh'/MM.106 trees were

planted in 1977 in north-south rows at a spacing of 3.0 × 4.9 m (680 trees/ha) on a moderately well-drained Walsher soil composed of 40 to 100 cm of sandy-loamy material over glaciolacustrine clay. The trees were trained to the freestanding CL form (Tehrani et al., 1988). Because of vigorous tree growth, every other tree in each row was removed in Mar. 1986, producing a final spacing of 6.1 × 4.9 m (340 trees/ha).

In Apr. 1987, a trial composed of seven randomized complete blocks was estab-

lished. Each block contained three adjacent trees pruned to maintain the CL tree form and three adjacent trees converted to the PL tree form by removal of east- or west-oriented upper scaffolds, as described by Lakso et al. (1989). In early Spring 1988 and 1989, CL trees were pruned as normally recommended for dormant trees (Tehrani et al., 1988); PL trees were pruned following the same recommendations while maintaining the narrow profile of the upper canopy. No summer pruning was carried out during this trial.

Light distribution was measured after terminal-bud formation within the canopies of three CL trees and three PL trees, chosen at random, on 21 July 1989, a lightly and uniformly overcast day. Photosynthetic photon flux (PPF) was determined at 75-cm grid points at six elevations from the soil surface on an east-west and a north-south transect through the center of the canopy of each tree using a LI-COR Model 185A quantum sensor (LI-COR, Lincoln, Neb.). Readings were taken between 1100 and 1500 HR Eastern Daylight Time (EDT) (solar noon occurred at 1320 HR EDT).

Fruit number and yield were determined for each tree at harvest each year. In 1987, one composite fruit sample of ≈12 kg was taken from throughout the canopies of each three-tree plot at normal harvest. In 1988 and 1989, a similar-sized fruit sample was collected separately from the upper and lower halves of the canopies of each three-tree plot. Fruit samples were stored in air at 0°C until color ratings were taken. A 25-fruit subsample, selected at random from each harvest sample, was evaluated for fruit color by visually rating the percentage of the surface of each fruit covered with a solid red. Trunk circumference was recorded annually on each tree following leaf drop at a premarked lo-

Fig. 1. A single relationship describes the percentage of full photosynthetic flux within the canopies of palmette-leader (PL) and central-leader (CL) trees along both vertical and horizontal transects through the center of the tree. Vertical values are means of six observations; horizontal values are means of 12 observations.

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PALMETTE LEADER TREE

CENTRAL LEADER TREE

Fig. 2. Percentages of full photosynthetic photon flux along transects in palmette- (A, B) and central-leader (C, D) trees. Each value is the mean of three observations, except the center value at 1 m high, which is the mean of nine observations.

Table 1. Effects of central-leader (CL) and palmette-leader (PL) tree forms on yield and fruit size of 'McIntosh'/MM.106 apple trees.

Tree form ²	Yield per tree (kg)				Mean fruit wt (g)			
	1986	1987	1988	1989	1986	1987	1988	1989
CL	96 a	107 a	131 a	174 a	170 a	150 a	130 a	120 a
PL	92 a	79 b	109 a	109 b	150 a	150 a	130 a	120 a

²PL pruning Apr. 1987. Mean separation within columns by analysis of variance ($P = 0.05$). Each value is the mean of seven observations.

Table 2. Effect of central-leader (CL) and palmette-leader (PL) tree forms on yield efficiency and trunk cross-sectional area (TCSA) of 'McIntosh'/MM.106 apple trees.

Tree form ²	Yield efficiency (g/cm ² TCSA)				TCSA 1986 (cm ²)	Annual TCSA increment (cm ²)			TCSA 1989 (cm ²)
	1986	1987	1988	1989		1987	1988	1989	
CL	800 a	730 a	820 a	920 a	127 a	25 a	16 a	24 a	192 a
PL	780 a	550 b	690 b	600 b	122 a	25 a	16 a	27 a	190 a

²PL pruning Apr. 1987. Mean separation within columns by analysis of variance ($P = 0.05$). Each value is the mean of seven observations.

cation on the trunk 30 cm above the soil surface. Mid-shoot leaves from current-season's shoot growth were collected as a composite sample from each three-tree plot each

August and processed for foliar analysis according to the methods of Bodnar et al. (1983).

For data other than foliar analysis, plot

means were calculated from the sampled fruit or the three trees comprising each plot before statistical analysis. All percentages were transformed using the arcsin of the square root before analysis. Analyses of variance were carried out using the General Linear Models (GLM) procedure of the Statistical Analysis System (SAS) program package (SAS Institute, Cary, N.C.).

The percentage of diffuse PPF was curvilinearly related to depth in the canopy in the same manner along both vertical and horizontal transects from the outer edge of the canopy to the center of the tree (Fig. 1). Neither tree form nor transect direction affected the pattern of light penetration. Light levels within the canopies of both CL and PL trees were similar to those observed in other studies (Barritt et al., 1987; Heinicke, 1963, 1964). Light levels fell below 30% full illumination in the interiors of both tree forms, due, in part, to the development of some vigorous shoot growth from the newly exposed upper portion of the lower whorl of scaffold limbs in the PL trees. The absence of differences between CL and PL trees in light penetration along either horizontal or vertical transects suggests that PL pruning alone did not alter leaf area index (Jackson and Palmer, 1972). The pattern of light distribution within the canopies of both tree forms in this study (Fig. 2) closely paralleled the estimated light distribution values for summer-pruned trees reported by Lakso et al. (1989).

Foliar analyses revealed no significant differences in macronutrient levels between tree forms in any of the 3 years (data not shown).

Yield per tree was reduced by 27% in PL trees in 1987, the year the PL tree form was established (Table 1). This result would be expected where significant pruning is required to adjust tree structure. Lakso et al. (1989) reported no yield loss in either of the 2 years during which a portion of the trees in their study was converted to the PL form. This observation suggests that less pruning was required to establish the PL tree form in their trees.

Yield per tree was unaffected by tree form in 1988, but was again significantly lower for PL trees in 1989 (Table 1). Average fruit size was unaffected by tree form in any of the 3 years reported here. However, yield efficiency was reduced in all 3 years in PL trees (Table 2), likely as a consequence of the change in canopy volume-trunk cross-sectional area (TCSA) relations produced by imposition of the PL tree form. Lakso et al. (1989) reported improved yields from summer-pruned PL trees 1 to 2 years after conversion, presumably due to greater productivity from spurs previously poorly exposed to light. Lakso and Goffinet (1987) suggested improved fruit size from PL trees in their early trials, but Lakso et al. (1989) reported no differences in fruit size in PL or CL tree forms. Canopy light levels recorded in this study suggest that the PL tree form alone may not sufficiently improve light distribution in more closely spaced trees in the absence of summer pruning to overcome the

Table 3. Effects of central-leader (CL) and palmette-leader (PL) tree forms on fruit color at harvest of 'McIntosh'/MM.106 apple trees.

Tree form ^z	Fruit surface with solid red (%)				
	1987	1988		1989	
	Portion of canopy				
	Entire	Top half	Bottom half	Top half	Bottom half
CL	28 a	46 a	37 a	30 a	17 a
PL	25 a	47 a	36 a	26 a	16 a

²PL pruning Apr. 1987. Mean separation within columns by analysis of variance ($P = 0.05$). Each value is the mean of seven observations.

yield loss accompanying initial scaffold-limb removal. TCSA growth was unaffected by tree form in this study.

Fruit samples collected in 1987, 1988, and 1989 showed no differences in fruit color development due to tree form, although effects of year are evident (Table 3). These observations are consistent with the absence of tree-form effects on canopy light distribution. Lakso et al. (1989) also reported no difference in fruit color between PL and CL tree forms, but attributed this absence of difference to the annual summer pruning applied to their trees. Other fruit-quality characteristics were not examined in this study.

The results reported here suggest that imposition of the PL tree form on mature 'McIntosh' trees can have detrimental effects on yield without improvement of light distribution or fruit quality in the first 3 years after conversion. The effectiveness of this management method for improving yield, fruit size, or fruit quality may be limited by tree size, tree spacing, or the need for supplemental summer pruning.

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