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The Correlation of Light Interception with Yield and Fruit Color of McIntosh Apple Strains

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Abstract

Light interception by a 0.89 ha orchard of regular (non-spur) and spur-type strains of McIntosh' on dwarfing (M.26) and semi-vigorous rootstocks (MM106 and MM111) was measured by fish-eye photography in the 7th and 8th growing seasons. Yield was linearly dependent on light interception by the trees. Fruit color of the non-spur strains was similar to but poorer than that of the spur-types.

Introduction

'McIntosh' is the most important apple cultivar grown in the Eastern United States (13), and in Canada (9). Following the introduction of natural spur-type 'McIntosh' strains, especially those that bear high quality fruit (1,5) their suitability for present day orchard management has been questioned (6, 12).

Earlier oral reports (8, 10) indicated that regular or non-spur strain 'McIntosh' trees were larger than spur-types, had more branches, and carried the largest crops at all spacings. However, spur-types had more flower buds on 2-year-old wood, and fruit color was better.

Generally, total dry matter accumulation of crops is linearly related to the amount of light intercepted by the foliage during the growing season (7). In apples, this relationship is complicated by a complex tree structure, particularly in mature trees. However, Jackson (2) has shown that with 4-year-old 'Golden Delicious'/M.9, where maximum leaf area index did not exceed 1.8, yield was linearly dependent on light interception by the trees. The design of orchards to maximize total light interception while avoiding shade in the fruiting zones will be facilitated by a greater understanding of the quantitative relationships between light interception and apple yield and quality. This report shows the influence of light interception on yield and fruit color of 7 and 8-year-old 'McIntosh' apple strains.

Materials and Methods

In the spring of 1971 a 0.89 ha (2.2 acre) research orchard was planted in Caledon sandy loam soil at the Horticultural Experiment Station, Simcoe, in Southern Ontario, using non-spur and spur strains of 'McIntosh' purchased from commercial nurseries. 'Geneva McIntosh' on MM.106 and 'Rogers McIntosh' on M.26 were the non-spur strains used, while the spur-types were Macspur on MM106, MM.111 and M.26 and Morspur on MM.106. A summary of the scions, rootstocks and the spacing combinations are given in Table 1.

The experimental design was a split-plot with the main plots as spacings arranged as a randomized complete block design with 3 blocks. Strain-rootstock combinations were allocated to sub-plots, with a minimum of 4 trees per sub-plot.

After the third year in the orchard the trees were allowed to carry a crop and fruit yield per tree was recorded. Each year fruit color was evaluated subjectively, by estimating the % fruit surface which had acquired a red color, on a random sample of 30 fruits from each strain/rootstock combination all at the 2.44 m x 4.27 m (8 ft. x 14 ft. spacing, in each block.

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Table 1. Scions, rootstocks and the spacing combinations.

		Tree Spacings (m)[z]			
Scion	Rootstock	5.49 × 7.32	3.66 × 5.49	2.44 × 4.27	1.83 × 3.66
Geneva	106	x	x	x	
Rogers	26			x	x
Macspur	106	x	x	x	
Macspur	111	x	x	x	
Macspur	26			x	x
Morspur	106	x	x	x	

[z]Tree spacing equivalents:
5.49 × 7.32 m gives 249 trees/ha (18 × 24 ft., 101 trees/ac)
3.66 × 5.49 m gives 500 trees/ha (12 × 18 ft., 202 trees/ac)
2.44 × 4.27 m gives 960 trees/ha (8 × 14 ft., 389 trees/ac)
1.83 × 3.66 m gives 1494 trees/ha (6 × 12 ft., 605 trees/ac).

Fisheye photographs (Fig. 1) were taken at the mid-point between 4 trees of each strain at each spacing in each block using methods similar to those of Lakso (3). The photographs were taken with a single lens reflex camera fitted with a Nikkor 180° lens with a focal length of 7.5 mm attached to a tripod 25 cm from the ground and pointed to the zenith. Black and white film (Kodak Plus-X, ASA 125) was used. With the edges of the photograph masked to improve precision, the central 60% of the photograph area was analysed by false color densitometry to determine the percent sky obscured by the tree (3). Light incident on the camera location was measured with a quantum sensor attached to a Li-Cor meter. Fisheye photographs and light measurements were taken on several overcast days from late June (about the time of terminal bud set) to late September in the 7th and 8th growing seasons.

Results and Discussion

Light interception and yield. The percent tree on the fisheye photographs (Fig. 1) was well correlated (r = 0.83) with the light received as measured with a quantum sensor. This agrees well with Lakso (3) who showed that r = 0.87 in similar work within apple tree canopies.

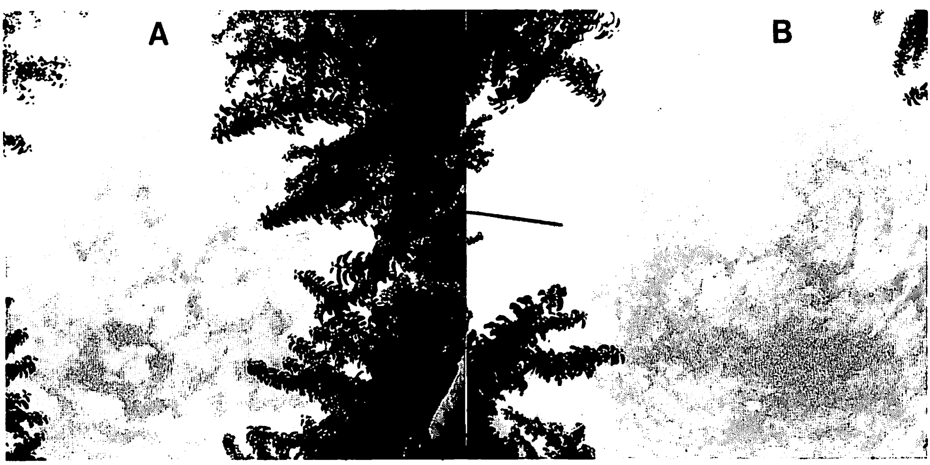

Figure 1. Fisheye photographs of "Macspur McIntosh" apple trees on (A) MM.106 and (B) on M.26 rootstock on June 19 in their 8th year. The trees were planted at 2.44 m × 4.27 m. The line at the center left of each photograph is a north marker.

Yield of 7- and 8-year-old trees of 'McIntosh' and its spur-types was linearly dependent on light interception by the trees (Fig. 2 and Table 2), in agreement with results for 4-year-old 'Golden Delicious' on the most dwarfing commercially available rootstock, M.9 (2). This yield/light interception relationship would therefore appear to hold for older trees (at least to 8 years), for trees on rootstocks of different vigor, and for trees planted at different spacings.

The coefficient of determination (R^2 as %) for the regression of yield on light interception was high in all cases, except for the dwarfing rootstock (M.26) in the 8th year (Table 2). This may indicate a limitation of this technique due to a non-linear relationship when relatively small trees have reached, or are approaching, a balance between fruit yield and vegetative growth. The slope of the line for M.26 was greater than for semi-vigorous rootstocks in the 7th year and increased from the 7th to the 8th year for the semi-vigorous rootstocks (Table 2). The slope for trees on all rootstocks in the 8th year (1.40 t/ha for each % increase in light interception) is similar to the value of 1.30 reported by

Table 2. Linear regression analysis for yield (t/ha) and percent of light intercepted by McIntosh strains on different rootstocks during the 7th and 8th growing seasons.

Growing season	Rootstocks[z]	n	Slope[y] (t/%)	R^2 (%)	C.V.
7th	Semi-vigorous	36	0.45	76.9	25.2
	Dwarfing	12	0.64	70.9	21.8
	All	48	0.48	67.9	28.3
8th	Semi-vigouous	36	1.51	81.3	30.8
	Dwarfing	12	0.42	24.9	23.5
	All	48	1.40	74.8	32.9

[z]Semi-vigorous rootstocks were MM.106 and MM.111 while dwarfing was M.26.
[y]Tons per hectare increase for each percent increase in light interception.

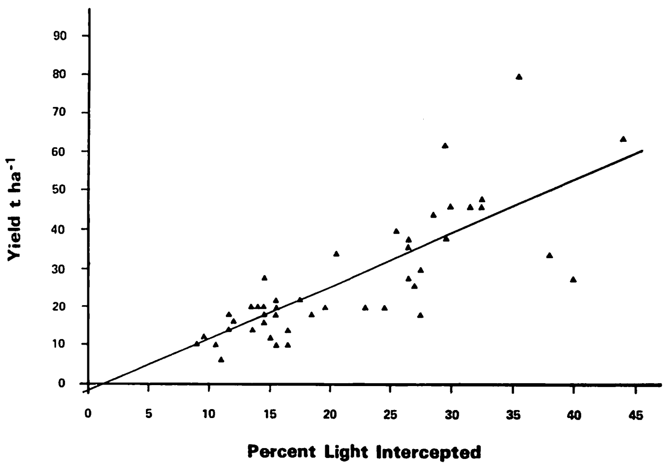

Figure 2. Yield of McIntosh apple strains in their 8th year in the orchard in relation to light interception (as % of the tree on fisheye photographs). The trees were planted at a range of plant populations from 249 to 1494 trees/ha in a spacing trial. The equation to the line is yield = 1.4% light intercepted -3.2.

Jackson (2). Further work is needed to determine the relationship between the efficiency of photosynthesis per unit of light energy absorbed and economic yields of different cultivars and rootstocks.

Fruit color. Fruit color of the two regular or non-spur 'McIntosh' strains was similar in both years and was not influenced by rootstock (Table 3), although yield per tree was about doubled on the more vigorous rootstock (MM.106) as compared to the dwarfing M.26. In contrast, Proctor et al. (11) reported that better fruit color was obtained on trees grown on M.26 than those on the more vigorous M.7, with a similar rootstock effect on yield. Apple color is positively correlated with global radiation reaching the fruit (11). In young trees, all fruit are probably receiving enough light to ensure adequate red color at harvest, whereas with more mature trees, fruit color will be affected by the influence of the rootstock on tree size, yield, total light interception and shading within the fruiting zone. Fruit color of spur-type strains was superior to that on regular strains, particularly in the 8th year (Table 3).

Lakso (4) has stressed the use of fisheye photographs taken at various locations within the canopy for evaluating canopy densities in relation to light climate within the canopy, and to flowering and fruit coloration. Our results complement those of Lakso (4) and suggest the use of such photographs in relating light climate to yield of trees and to color of fruit in cultivar and spacing trials.

Table 3. Mean fruit color (percent red) of 'McIntosh' apples from 7- and 8-year-old regular (non-spur) and spur-type trees planted at 2.44 m × 4.27 m in the orchard.

	Rootstock vigor and scion					
	Semi-vigorous				Dwarfing	
Year	Regular (Geneva) /MM.106	Macspur /MM.106	Morspur /MM.106	Macspur /M.111	Regular (Rogers') /M.26	Macspur /M.26
7th	44 b[z]	48 b	48 b	57 a	42 b	56 a
8th	42 c	53 b	58 ab	55 b	39 c	62 a
Mean	43	50.5	53	56	40.5	59

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

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