Production Efficiency of a Large and a Small 'McIntosh' Apple Tree[1]

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Abstract. **There were no differences between a large (29.0 ft branch spread) and a small (10.5 ft branch spread) 'McIntosh' apple tree in total dry matter accumulated per unit of occupied land. However, the small tree produced 80.6% more fruit on a unit area basis. In terms of leaf efficiency, the small tree produced 60.4% more dry matter per unit weight of leaves than the large tree.**

In recent years, apple growers in all major producing areas have expressed a strong preference for smaller trees. Size-controlling rootstocks, compact spur-types, and special training and pruning techniques have been employed, singly and in combination, in efforts to develop and maintain smaller trees. The anticipated advantages of the smaller trees include easier management, earlier bearing, higher quality fruit, and higher yields, but not all of these have been satisfactorily demonstrated under experimental conditions. In a discourse on the performance of trees of various sizes, Cain (1) concluded that there was a negative correlation between tree spread and fruit production per square foot. He reported that a tree with a 32 ft branch spread produced only about one-half as much fruit per unit area of land occupied as a tree with an 8 ft branch spread. Heinicke (4) has shown that small trees have a greater percentage of their leaf area exposed to optimum sunlight than do large trees. This suggests that differences in productivity might be due to greater leaf efficiency. On the other hand, most large trees have a great bulk of unproductive wood. Since this wood competes with the fruits for the products of the leaves, the support of an inordinate amount of unproductive wood might account for the lower fruit productivity of large trees. Hatton (2) and Preston (6, 8, 9) studied the relationship between fruit and wood production by comparing yields over a period of years with total accumulated scion weight, but their results were expressed on a fresh weight basis and did not include leaves. The purpose of this study was to determine the amounts of leaf photosynthate, on a dry weight basis, that accumulated during a growing season in the fruits, leaves and wood of a large and a small 'McIntosh' apple tree.

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Total dry matter accumulation of a large 'McIntosh' apple tree was compared with that of a small tree for the 1969 growing season. The trees are described in Table 1. Each tree was typical of other trees in the same block and, since the two blocks were immediately adjacent, soil and site differences were minimal. The trees were not in adjacent rows and each was completely surrounded by trees of similar size. The large tree, while relatively old, was both vigorous and productive, and was fairly representative of large, mature 'McIntosh' trees in the Hudson Valley. The small tree had been in commercial production for 7 years and was apparently approaching maximum size and productivity.

At harvest the fruit, both picked and drops, was weighed, samples were taken from both trees for dry weight determinations, and the total dry weight of fruit was calculated for each tree. After harvest the leaves and the terminal shoots were removed, oven-dried, and weighed. Next the spurs were removed and the 1969 terminal growth (buds and cluster bases) were separated from the older wood. This fraction was then oven-dried and weighed. The fresh weight of the older spur wood was determined and then the inner phloem and the outer layer of xylem were removed from representative samples and dried and weighed. The dry weight of these tissues was expressed as % of the fresh weight of the entire sample and this percentage was used to calculate the increase in weight of all older spur wood. This value was added to the weight of buds and cluster bases to provide an estimate of total spur growth.

All branches of 1 inch in diameter, or less, were removed and the fresh weight determined. In most cases, this included

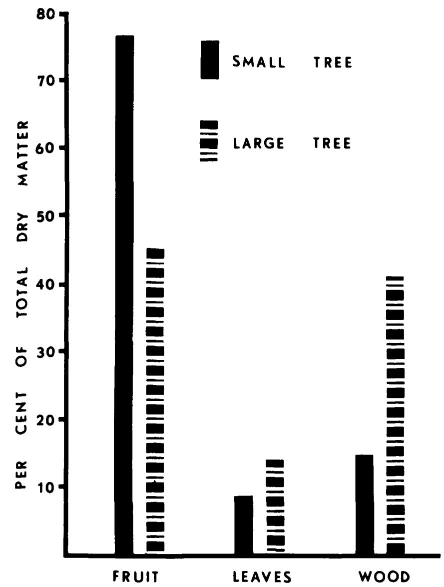

Fig. 1. Distribution of dry matter accumulated by large and small 'McIntosh' apple trees during the 1969 growing season.

wood 2 to 8 years of age. Representative branches that included segments from all ages in this range were collected from all parts of each tree and the inner phloem and 1969 xylem ring were separated from other tissues and dried and weighed. The dry weight of these samples was used to calculate the increase in dry weight of all small branches in the same way that the growth of the older spur wood was estimated.

The trunk and larger branches were cut into lengths of approximately 3 ft and the length and circumference at each end, at the wood-bark interface, were recorded. The outside area of each section was calculated by multiplying the length by the average of the 2 circumference values. Then 5 cores of wood were cut from each section with a 5/8 inch plug cutter in a power drill. The inner phloem and 1969 layer of xylem were separated from other tissues in the cores and dried and weighed. The increase in weight was calculated on the basis of dry weight per unit area of the cores. No effort was made to estimate the increase in dry weight of the root system.

Table 1. Description of 'McIntosh' apple trees used in production efficiency comparisons.

Attribute	Small tree	Large tree
Age in years	13	44
Rootstock	EM VII	Seedling
Structure	Central leader	Open center
Spacing - ft	14 x 20	35 x 40
Spread of branches - ft	10.5	29.0
Height - ft	10.3	25.3
Trunk circumference - inch	10.8	53.1
Yield - boxes	5.3	22.4

For convenience in weighing and in tabulating results, the weights were expressed in kg and the area occupied by the trees in m^2.

Total dry matter accumulation per m^2 of occupied land was essentially the same in both trees (Table 2). However, fruit production per m^2 of the small tree was 80.6% greater than that of the large tree. On the other hand, the large tree produced 2.6 times as much wood as the small tree.

Trunk cross-sectional area is often used as a measure of productive capacity and response to treatment (5, 7). In this study, the small tree produced more than 5 times as much fruit per unit of trunk cross-sectional area, and less than half as much wood, as the large tree.

The small tree had 34.0% less leaf tissue per unit area of occupied land than the large tree. This is in agreement with the results of Heinicke (4), who reported lower leaf area indices (LAI) for smaller trees. The small tree produced 60.4% more total dry matter per unit weight of leaves. In this case, greater leaf efficiency did not result in greater total dry matter accumulation per m^2 of occupied land because differences in leaf density offset differences in efficiency. However, this might not always be true because the differences in leaf density between the large and small trees compared in this study were greater than differences reported by Heinicke (4).

The distribution of the dry matter reveals significant differences between the trees (Fig. 1). In the small tree, 5 times as much dry matter went into fruit as into wood. In the large tree, the proportions of dry matter in fruit and wood were approximately equal. Heinicke (3) reported similar results with a somewhat larger tree. This reveals a fundamental disadvantage of the large tree; that is, a disproportionate amount of the products of photosynthesis may be diverted into the growth of unproductive wood. It would appear that this is a major factor contributing to the lower efficiency of large trees in fruit production. It is possible, of course, that the structure of the tree could influence its efficiency. A large central leader tree, with less unproductive wood and better light exposure of the foliage, might be somewhat more efficient than an open center tree with the same branch spread.

While the differences reported here are large and decisive, these data are not without limitations. No effort was made to estimate the increase in dry weight of the root system or the carbohydrates lost through respiration. It is assumed that differences in these areas would be proportional to other differences between the trees but, since one was a clonal rootstock and the other a seedling, this is not necessarily true. In any orchard, there are large individual differences between trees in size, structure, and productivity and trees of greater or lesser efficiency of both sizes undoubtedly exist. It is unfortunate that the nature of this investigation precluded the possibility of replication. However, extreme care was exercised in the selection of trees and these results should be fairly representative of many 'McIntosh' trees of these 2 sizes throughout the Hudson Valley.

Table 2. Relative efficiency of large and small 'McIntosh' apple trees in dry matter accumulation.

	Dry matter accumulated (kg) during the 1969 growing season[a]					
	Total		Per m^2		Per kg leaves	
Part of tree	Small tree	Large tree	Small tree	Large tree	Small tree	Large tree
Fruit	13.753	58.118	1.710	0.947	8.816	3.223
Leaves	1.560	18.029	.194	.294	-----	-----
Wood:						
Shoots	.072	2.343	.009	.038	.046	.130
Spurs	.331	2.958	.041	.048	.212	.164
Small branches	1.447	23.426	.180	.382	.928	1.229
Trunk and large branches	.738	24.112	.092	.393	.473	1.338
Total wood	2.588	52.839	.322	.861	1.659	2.931
Total	17.901	128.986	2.226	2.102	11.475	7.154

[a]Excluding roots.

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Dilution Technique for Calibration of Infrared Gas Analyzers for Use with Carbon Dioxide[1]

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Abstract. **A simple dilution technique is described for the calibration of infrared gas analysers for use with carbon dioxide. The technique involves determining the exact volume of a closed loop system, which includes analyser, circulating pump and connecting tubing. Successive dilutions with either known volumes of nitrogen gas with no carbon dioxide or span gas with known concentrations of carbon dioxide, provide a range of calculable concentration points from which the calibration curve can be plotted.**

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The need for verifying and developing calibration curves for infrared carbon dioxide analysers has been recognized. The curve can be developed by purchasing several gas cylinders of differing carbon dioxide concentrations to obtain desired points along the curve. The carbon dioxide