CROPPING EFFICIENCY, DRY MATTER AND NITROGEN DISTRIBUTION IN MATURE GENETIC DWARF AND STANDARD PEACH TREES

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Abstract

Mature, six-year-old standard and genetic dwarf peach trees [*Prunus persica* (L.) Batsch] were harvested and divided into their above-ground components to compare the cropping efficiency, dry matter and reduced nitrogen distribution characteristics of each phenotype. In addition to the expected differences in absolute amounts of total above-ground dry weight, reduced nitrogen content, and leaf area, there were significant differences in the way these components were distributed within the trees. The genetic dwarfs allocated a larger percentage of their above-ground dry matter to leaves, fine branches, and fruit and a smaller percentage to the larger wood component than did the standard trees. The compact, genetic dwarf tree canopies had larger amounts of leaf area and leaf nitrogen per unit of canopy volume but lower leaf nitrogen per unit of leaf area than standard trees. There were no significant differences between the two phenotypes with respect to leaf area per unit of ground area, fruit dry weight per unit leaf area, fruit dry weight per unit of leaf nitrogen, or fruit dry weight per unit of ground area.

1. Introduction

Crop productivity is dependent on the efficiency of photosynthesis or accumulation of dry matter and the allocation of photosynthates or dry matter to economic end-products (Cooper 1976). In agronomic crops large increases in productivity have been realized by selecting cultivars which allocate a greater proportion of their dry matter to economic end-products (Dalrymple 1980). Traditionally plant breeders of tree crops have concentrated primarily on fruit quality, harvest dates, and resistance characteristics and relied on rootstocks for obtaining size control. Genetically dwarfed tree cultivars appear to offer one possibility of increasing tree crop productivity through genetically altered patterns of dry matter allocation. Previous studies have shown that genetically dwarfed peach trees may have the potential for significantly increased cumulative crop productivity relative to standard-sized peach cultivars (Hansche *et al.* 1979, 1980).

The purpose of the present study was to compare the cropping efficiency, dry matter, and nitrogen distribution of the above-ground portions of mature genetically dwarfed and standard peach trees. An analysis of the reduced nitrogen distribution was included in this study because of the importance of nitrogen in tree growth and productivity and the interrelationships between leaf nitrogen content and photosynthesis (DeJong 1982).

2. Material and methods

The above-ground portions of four genetically dwarfed peach trees (Strain 54P455) and four standard-sized peach trees (Strains 13, 16-15 and 15, 7-14) were harvested in late August 1981 when the fruit was mature. All trees were six-years-old, budded onto Nemaguard peach rootstock, and grown in adjacent research plots at the Kearney Horticultural Field Station, Parlier, CA. The standard-sized trees were trained into a standard, open-vase configuration and received routine horticultural care. The genetic dwarfs were allowed to grow more naturally and received minimal pruning but otherwise received horticultural care similar to that of the standards. Both tree types were thinned to a commercially acceptable level the previous spring.

Prior to harvest the appropriate dimensions of each tree were measured so that the canopy volume and projected soil surface area could be estimated.

At harvest the total above-ground dry matter was separated into five fractions: large wood (>2 cm diameter), small wood (<2 cm diameter), leaves, fruit flesh and fruit pit. Nitrogen content was determined on a minimum of six subsamples of each fraction using an automated Kjeldahl analysis technique (Carlson 1978).

3. Results

The mean total leaf area, above-ground dry weight and above-ground nitrogen content of the genetic dwarf trees were approximately 30, 22 and 29% of the standard trees, respectively (Table 1). The large differences in leaf area, dry weight, and nitrogen content are reflected in each of the component parts of the plants (Table 2), however, the relative differences between tree types varies with each plant part. For example, the small wood component of the genetic dwarf trees was 50% as great as that of the standard trees but the large wood component of the genetic dwarfs was 12% as large as the standard trees. The differences in dry matter and nitrogen allocation within each tree type are more clearly demonstrated in their relative distributions of dry matter within each tree type (Tables 3 and 4). In the genetic dwarfs a significantly greater proportion of the total above-ground dry matter was allocated to the fruit than in the standard trees.

The leaf area index (LAI, leaf area per unit of ground area) of both tree types was not significantly different but the leaf area to canopy volume ratio (LAVR) of the genetic dwarf trees was significantly greater than the standard trees (Table 5). Both tree types produced similar amounts of fruit per unit of leaf area and ground area but the genetic dwarfs produced significantly more fruit per unit of total above-ground dry matter (Table 5).

Although the relative leaf nitrogen concentration of both tree types was similar (2.61 S.E. ± 0.08% and 2.74 S.E. ± 0.03% for genetic dwarf and standard trees, respectively) the mean leaf nitrogen per unit leaf area of the dwarf trees was significantly less than the standard trees (Table 6). However, because the canopy of the dwarf trees was more dense, the mean leaf nitrogen to canopy volume ratio of the genetic dwarf was still significantly greater than the standards. There were no significant differences in the amount of fruit produced per unit of leaf nitrogen or total above-ground tree nitrogen (Table 6).

4. Discussion

Research with size controlling rootstocks in apple trees indicates that smaller trees can have a higher production efficiency than larger trees (Forshey et al. 1970). The increased production efficiency of small apple trees has been attributed to increased leaf light interception (Heinicke 1964, Jackson 1980) and to increases in the efficiency of dry matter partitioning (Landsberg 1980).

The use of genetic dwarfing in peaches to obtain smaller trees does not appear to offer the same potential advantages as does the use of size controlling rootstocks in apples. Although tree size was significantly reduced and a greater proportion of the above-ground dry matter was in fruit there were no significant increases in fruit production per unit of leaf area, fruit production per unit of ground area that the tree covered, or fruit production per unit of leaf or tree nitrogen.

The lack of production efficiency differences in spite of increases in the proportion of above-ground dry matter allocated to fruit may be a result of decreases in leaf photosynthetic efficiency. The genetically dwarfed peach trees are noted for their extremely dense, compact tree canopies. This is exemplified by the maintenance of high leaf area indices in the dwarf canopies even though tree height is substantially reduced. In this study this resulted in a greater than 50% increase in the leaf area to canopy volume. With LAI's as high as 10 such a large increase in the amount of leaf area per unit of volume undoubtedly reduces the total amount of radiation available to, and the daily assimilation rate of, the average leaf in the dwarf canopy in comparison with the standard canopy. The decreased leaf nitrogen content per unit leaf area of the genetic dwarfs provides indirect evidence that the photosynthetic capacity of the average dwarf tree leaf may also be less than the standards (DeJong 1982). Recent research in our laboratory indicates that leaf photosynthetic capacity and leaf nitrogen content per unit leaf area are correlated with daily leaf radiation exposure (unpublished data). Thus, the lower mean leaf nitrogen content per unit of leaf area of the dwarf trees may be related to lower mean daily exposures to solar radiation.

Although this study does not indicate an increase in annual production potential of genetically dwarfed trees compared to standard trees at maturity, genetic dwarfs have been shown to offer the opportunity to increase early yields by planting at higher densities and to reduce orchard production costs by reduction of tree height (Hansche et al. 1979).

5. Acknowledgements

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6. References

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Table 1. Mean (± S.E.) total leaf area, above-ground dry matter, and reduced nitrogen content of six-year-old genetic dwarf and standard peach trees at harvest.

Phenotype	Leaf Area (m^2)	Dry Matter (Kg)	Nitrogen (g)
Dwarf	78.2 ± 0.9	35.3 ± 1.9	366.5 ± 15.5
Standard	258.6 ± 20.6	160.0 ± 15.1	1273.5 ±106.6

Table 2. Mean (± S.E.) dry matter of components of six-year-old genetic dwarf and standard peach trees at harvest.

Phenotype	Dry Matter (Kg) Leaves	Small Wood <2 cm	Large Wood >2 cm	Fruit Flesh	Fruit Pit
Dwarf	5.86 ±0.10	8.58 ±0.43	10.96 ±0.66	7.96 ±0.63	1.91 ±0.24
Standard	21.40 ±1.64	17.02 ±2.08	88.26 ±10.25	27.34 ±2.50	6.00 ±0.49

Table 3. Dry matter of each component relative to the total above-ground dry matter of six-year-old genetic dwarf and standard peach trees at harvest.

Phenotype	Percent Dry Matter Distribution Leaves	Small Wood <2 cm	Large Wood >2 cm	Fruit Flesh	Fruit Pit
Dwarf	16.7	24.3	31.0	22.5	5.3
Standard	13.5	10.6	54.7	17.3	3.8
LSD .05	3.0	1.9	4.8	3.4	1.4

Table 4. Nitrogen content of each component relative to the total above-ground nitrogen content of six-year-old genetic dwarf and standard peach trees at harvest.

Phenotype	Percent Nitrogen Distribution				
	Leaves	Small Wood <2 cm	Large Wood >2 cm	Fruit Flesh	Fruit Pit
Dwarf	42.7	18.4	9.6	26.2	3.1
Standard	46.3	8.4	21.0	21.0	3.3
LSD .05	6.2	2.2	3.6	5.1	1.0

Table 5. The leaf area index (LAI), leaf area to canopy volume ratio (LAVR), fruit to leaf area ratio (FLAR), fruit to ground area ratio (FGAR), and fruit dry matter to total above-ground dry matter ratio (FTR) of six-year-old genetic dwarf and standard peach trees at harvest.

Phenotype	LAI ($m^2 \cdot m^{-2}$)	LAVR ($m^2 \cdot m^{-3}$)	FLAR ($g \cdot m^{-2}$)	FGAR ($Kg \cdot m^{-2}$)	FTR ($g \cdot g^{-1}$)
Dwarf	10.2	4.66	126.3	1.28	0.39
Standard	11.1	3.07	130.4	1.43	0.27
LSD 0.05	1.4	0.65	39.8	0.29	0.08

Table 6. The leaf nitrogen content to leaf area ratio (LNAR), leaf nitrogen to canopy volume ratio (LNVR), fruit dry matter to leaf nitrogen ratio (FLNR) and fruit dry matter to above-ground tree nitrogen ratio (FTNR) of six-year-old genetic dwarf and standard peach trees at harvest.

Phenotype	LNAR ($g \cdot m^{-2}$)	LNVR ($g \cdot m^{-3}$)	FLNR ($g \cdot mg^{-1}$)	FTNR ($g \cdot g^{-1}$)
Dwarf	0.199	0.926	0.634	38.2
Standard	0.227	0.700	0.581	35.2
LSD .05	0.021	0.150	0.222	11.6