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THE ANNUAL PRODUCTION AND UTILIZATION OF DRY MATTER OF AN AVOCADO (*Persea americana* Mill.) TREE

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SUMMARY

This work, which was a part of the M.Sc. studies in the Faculty of Agriculture in the Hebrew University of Jerusalem, was carried out under the supervision of Prof. E.E. Goldschmidt. Two basic processes which take place concurrently in the avocado tree during the yearly cycle of growth and reproduction are discussed in this essay: Dry matter production and its utilization.

Key Words: Tree physiology, reserves, productivity.

INTRODUCTION

The production of dry matter and its distribution among plant organs are basic processes on which other internal activities are dependent. Therefore it is important to study the carbon balance of the avocado tree.

The objective of this essay is to compile a dry matter budget for a fruiting avocado tree and to find its relations to the yearly avocado growth cycle.

Eventually, this dry matter budget may be part of a dynamic avocado productivity model, as developed for citrus by Harpaz *et al*. (1990) and for other crops. The data presented in the essay are based on photosynthetic measurements made in Israel under Israeli climatic conditions, but important data from worldwide sources are included.

The data, calculations and estimations presented in this paper, refer to an avocado tree which reaches a canopy surface area of 50 m^2 by the end of September. Such a tree has been defined a “standard” tree.

The main data which are presented in following sections are based on photosynthetic measurements made by Sharon & Bravdo (unpublished) on the south quadrant of a ‘Hass’ avocado tree, on the dry matter content of ‘Hass’ avocado tree tissues presented by Lovatt (1996), on the avocado fruit growth presented by Ofer (1986) and on the yearly growth of the perennial parts of an avocado tree which grows in a commercial orchard.

The basic figures

Four rounds of photosynthetic measurements, with an interval of two hours, conducted on September 21, 1977 (12 hours of daylight) on the external layer of the south quadrant of a 'Hass' avocado tree, revealed that the daily assimilation of a quadrate meter was 0.21 mol CO_2. This figure refers to the hours of direct sunlight as well as to indirect lighting during the day.

According to this figure, estimates of the assimilation of the east, west and north quadrants have been made. So, it follows that the daily assimilation rate of an avocado tree, with an external canopy surface of 50 m^2 is 5.18 of CO_2.

According to data on reduced light intensity which reaches leaves on the inner, shaded parts of the tree (Schaffer and Andersen, 1994), it was estimated that for the whole tree, those leaves assimilate 1.9 mol of CO_2 per day. So, the total daily assimilation of an avocado tree is 7.08 mol of CO_2, which are 311.5 gram of CO_2.

Factors which influences the assimilation rate

The impact of each of the following five factors on the monthly assimilation rate of an avocado tree was calculated: leaf age, day length, yearly canopy growth, eastern dry wind stress, and climatic conditions during winter.

<u>Leaf age</u>

1.1) The life span of an avocado leaf is approximately one year.

1.2) The flush of avocado leaves and their shedding occurs in an uneven rate all year long (mostly between April and July).

1.3) The maximum assimilation efficiency of avocado leaves is attained between the 25^{th} and 70^{th} day after sprouting. Afterwards, their assimilation efficiency declines gradually towards senescence.

These are the physiological facts according to which the term "assimilation potential" has been defined.

"Assimilation potential" is the monthly assimilation yield, in mol CO_2, of an avocado leaf, calculated according to the order of the leaf flush and age. This factor refers to the internal capability of the leaf to assimilate CO_2.

Day length, eastern dry wind stress and climatic conditions during winter, are external factors that have an impact o the leaf's assimilation rate.

<u>The adjustments of the monthly assimilation potential</u>

As mentioned earlier, our estimate of the assimilation of an avocado tree, 7 mol of CO_2 per day, or 210 mol of CO_2 per month, was calculated according to photosynthetic measurements made on September 21, when the hours of daylight equal those of darkness.

During spring, the number of light hours that extend by 5.5% per month while during autumn they are reduced at the same rate. Therefore, the monthly assimilation potential has been adjusted accordingly: the first adjustment.

It was estimated that the seasonal growth of the canopy's outer layer area of an avocado tree in a commercial orchard reaches during summer, about 14%. Most of this yearly growth is vertical. The second adjustment of monthly assimilation has been done according to this estimation.

The reduction of the monthly assimilation rate, caused by climatic conditions, such as spring east dry winds and the winter climate, was the third adjustment. The third adjustment has been done according to data provided by The Israeli Meteorological Service.

The figures of the calculated monthly assimilation of an avocado tree, after the three adjustments mentioned earlier, are presented in Table 1, line 2. According to the figures, the highest monthly assimilation of 216 mol of CO_2 is gained in August by the "standard" avocado 'Hass' tree, while the lowest monthly assimilation occur in February.

According to the figures, the calculated monthly assimilation of an avocado tree in January and in February are only about 29% of the potential monthly assimilation, while in August it is about 97% (Table 1, line 2/1). The monthly gap between the calculated (actual) assimilation of an avocado tree and its assimilation potential, demonstrates mostly the influence of climatic conditions and canopy growth, on the avocado's assimilation performance.

Table 1. The calculated monthly assimilation rate and the assimilation potential of a "standard" avocado tree (mol of CO_2 per month).

Month:	**A**	**M**	**J**	**J**	**Au**	**S**	**O**	**N**	**D**	**J**	**F**	**Ma**
1	86	100	133	172	222	210	196	168	159	146	123	112
2	55	82	118	162	216	210	156	120	73	43	36	51
2/1	0.63	0.82	0.89	0.94	0.97	1.00	0.80	0.71	0.46	0.29	0.29	0.46

Month: from April to March.
1: The monthly assimilation potential of an avocado tree in mol CO_2.
2: The calculated monthly assimilation in mol of CO_2
2/1: The ratio of calculated monthly assimilation to the assimilation potential of a "standard" avocado tree.

The yearly growth of an avocado tree

In order to evaluate the yearly dry matter production, the following information was taken into account: Data presented by Cameron (1952) and Lovatt (1996) about avocado trees that were dismembered into organs. Their fresh and dry weights were reported; and growth rates of avocado shoots and roots measured in a rhizotron by Ploetz *et al*. (1992).

The following assumptions were made for the compilation of Table 2:
· A crop of 53.6 kg, F.W. per tree (1500 kg, F.W. per dunam).
· A yearly growth rate of 14% of the perennial organs.

· A flesh/seed ratio of 84/16 in the avocado fruit.

Table 2. The yearly utilization of dry matter in the organs of an avocado tree.

	Fresh weight (g)	Dry Matter (%)	Dry Matter (g)	Yearly Addition (%)	Yearly addition of fresh weight (g)
Perennial Organs:	176300	44.3	78100	14	10934
New organs: Roots	4100	37.1	1523	100	1523
Shoots	1200	36	430	100	430
Leaves	24000	40	9600	100	9600
Inflorescences	8094	20.2	1643	100	1643
Total: (Without fruit)	213694	42.7	91296	26.4	24130
Fruit:	53571				
Fruit flesh (84%)	45000	21	(9450)		
F.f.con.			14660		
Fruit Seed (16%)	8571	40	3428		18088
Total: (including fruit)	267265	44.9	109384	38.6	42218

Perennial organs: scaffold roots, trunk and branches.
FW (g): fresh weight, grams.
DW (g): dry matter, grams.
F.f.con.: Oil and protein in the fruit flesh converted to equivalent carbohydrate units.

The yearly growth of every organ, presented in the Table 2, has been divided to months according to data from research reports, or to the author's assumptions, when no data were available (Table 3).

Table 3. The monthly increase in dry matter of an avocado tree (total 42218).

Month:	**Ma**	**A**	**M**	**J**	**J**	**Au**	**S**	**O**	**N**	**D**	**J**	**F**
WF	2147	1705	3507	4017	4003	3317	1713	1121	830	734	619	417
Fruit			123	261	1933	3663	5345	6763				
Total	2147	1705	3630	4278	5936	6980	7058	7884	830	734	619	417

Month: from March to February
WF: Without fruit.

The energy balance of the growing avocado fruit

The periodic accumulation of all energy comprising components in an avocado fruit were calculated, while the fruit's own photosynthetic carbohydrate production was estimated for the same periods.

The calculations were based on the periodical measurements of net efflux of CO_2 of attached avocado fruit cv. Booth 7, which enabled Whiley *et al*. (1992) to calculate the fruit photosynthesis, and on data of fresh weight and oil content accumulation of growing 'Fuerte' fruits, presented by Ofer (1986).

The periodical dry matter weight of fruits, presented in both studies, has been used as "connection numbers". That means, that the rate of assimilation, recorded in a 'Booth 7' fruit of a certain dry matter weight, were related to a 'Fuerte' fruit with the same dry matter weight.

The calculations have been made for fruits during the first period of 10 weeks after anthesis and afterwards for fruits during 8 periods, of two weeks each, until the 26th week after anthesis (Table 4).

Table 4. Self produced energy of an avocado fruit and its percentage of the total energy accumulated in a fruit unit.

(1) Weeks After Anthesis	(2) Fruit Fresh Weight (g)	(3) Oil in Fruit (%)	(4) Fruit Assimilation of CO_2 ($nmol \cdot fruit^{-1} \cdot s^{-1}$)	(5) Energy Produced in 1 Hour Fruit Assimilation (Kcal)	(6) Fruit Self assimilation Percentage of Fruit Total Accumulated Energy (%)
10	12		3	0.0074	**21.3**
12	32		10	0.0247	**9.5**
14	58	2.8	18	0.0445	**8.3**
16	100	2.6	30	0.0740	**10.9**
18	135	3.5	38	0.0940	**12.0**
20	163	4.7	47	0.1160	**12.9**
22	181	7.1	50	0.1240	**13.3**
24	208	7.9	53	0.1310	**12.6**
26	235	9.7	55	0.1360	**10.7**

The figures presented in Table 3, indicate that there are two main periods during fruit growth, connected to the fruit's own photosynthetic activity.

1) The first ten weeks after anthesis, when the fruit's self assimilation provides about 20% of the total energy which accumulates in the fruit.
2) The remaining growing period, from the eleventh week on, when the fruit's self assimilation provides only about 10% of its accumulated energy.

This is the place to remind that in the spring season the assimilation efficiency of most of the previous year leaves are reduced towards shedding. At that time the new flushing leaves are still a sink for assimilates rather than a source. During this period a quick reduction in the starch reservoir level takes place in the avocado tree.

Those facts emphasize the importance of the self assimilation of the young fruits for their development and survival.

According to the figures in column (4) Table 4, the fruit's self assimilation increases constantly during the period of fruit growth but its share, out of the total dry matter accumulated in the fruit, is reduced.

The yearly production and utilization of dry matter in an avocado tree

Since the monthly assimilation and the monthly increase in dry matter of an avocado tree have been presented, it is now possible to calculate the production and utilization of an avocado tree during a year.

The calculation of the dry matter production has been made by multiplying the calculated monthly assimilation, given in mol of CO_2, by 30 g (the weight of 1/6 mol glucose) (Table 5).

In order to estimate the maintenance respiration rate (Rm) of an avocado tree, the weight of an uprooted 'Hass' tree, presented by Lovatt (1996), has been used. The utilization of dry matter for maintenance respiration has been calculated as 3% of the phytomass of the growing tissues between May and August, 2% during March, April, September and October, and 1% between November and February. The total monthly utilization of fry matter of an avocado tree is obtained by adding the monthly Rm to the monthly growth (Table 6).

Table 5. The monthly dry matter (g) production of a "standard" avocado tree.

Month:	Ma	A	M	J	J	Au	S	O	N	D	J	F
1.	1920	2445	2565	3600	4872	6486	6300	5280	4323	3480	2835	2385
2.			26	56	172	421	700	791				
1+2	1920	2445	2591	3656	5044	6907	7000	6071	4323	3480	2835	2385
%C		27.3	6.0	41.0	38.0	37.0	1.3					
								-13.3	-29.0	-19.5	-18.5	-16.0

Month: from March to February.
1. Monthly dry matter production by leaf. (The yearly total production per tree 46491 g D.M.)
2. Monthly dry matter production by fruit. (The yearly total production per tree 2166 g D.M.)
1+2: Total yearly dry matter production 48657g.
%C: The monthly change in dry matter production.

Table 6. The monthly utilization of dry matter (g) of a "standard" avocado tree.

Month	Ma	A	M	J	J	Au	S	O	N	D	J	F
1.Rm	232	203	310	316	323	329	224	228	114	114	114	114
2.Gr	2147	1705	3630	4278	5936	6980	7058	7884	830	734	619	417
1+2	2379	1908	3940	4594	6259	7309	7282	8112	944	848	733	531
%C		-20	106	16.6	36.2	16.8	-	11.4	-88.4	-10	-13.5	-27.6

Month: from March to February.
Rm.: Monthly maintenance respiration (The yearly total utilization 2621 g. D.M. per tree).
Gr.: Monthly growth (The total yearly growth 42218 g D.M. per tree).
1+2: Total yearly dry matter utilization: 44839 g. per tree.
%C: The monthly change in dry matter utilization, per tree.

Table 7. The monthly difference between production and utilization of dry mattering per tree of a “standard” avocado tree (Dif.). The accumulation of the monthly differences (Acc.).

Month:	Ma	A	M	J	J	Au	S	O	N	D	J	F
	-	+	-	-	-	-	-	-	+	+	+	+
Dif.		537							3379	2632	2102	1854
	459	1908	1349	938	1215	402	282	2041				
	-	+	-	-	-	-	-	-	-	-	+	+
Acc.		78									1964	3818
	459		1271	2209	3424	3826	4108	6149	2770	138		

Month: from March to February.

CONCLUSIONS

According to Table 7, during seven out of twelve months, the utilization of dry matter, of an avocado tree, exceeds its current production. During this period, the tree’s starch reserves are the source for the surplus demand of dry matter. It has been reported by Whiley and Wolstenholme (1990) that the starch reserves in the avocado trunk are reduced during the period of March to June. Yet, more information, about the starch reserves in other organs of the avocado tree is needed, in order to understand the carbohydrate utilization during the year.

It has to be mentioned that the data of this essay are based on an assumption that the whole crop has been harvested by the end of October. Any delay in the harvest date changes the utilization of dry matter during the winter period. The main dry matter production occurs in the avocado tree during the period of July to October (Table 6). But even during those months, the tree’s current assimilation does not supply its current demand for assimilates (with a crop of 1.5 per dunam).

According to Table 6, the utilization of dry matter in the avocado tree increases dramatically in May. The increase of the dry matter production is very low in this month (Table 5) (May is a month of heavy leaf shedding). It can be concluded that main factor of fruitlet drop, which occurs in May, is related to the tree’s lack of capability to supply sufficient carbohydrates to satisfy the current demands.

According to figures presented in the last column of Table 4, the self assimilation of the avocado fruit supplies about 20% of its energy accumulating components during the period of May and June. When the above mentioned shortage in carbohydrates is taken into account, the importance of the fruit self supply, although partial supply, comes into prominence.

There is no doubt that flowering is the main event, in the yearly cycle of every fruit tree, that determines its development The dry matter utilization in the avocado tree during March (Table 6), is about four times higher than during the previous month. This figure which present mainly the need for dry matter for flowering, 1643 g D.W. (Table 2) out of

2147 g D.W. total D.W. utilization for growth (Table 6), causes a deficiency in the current supply of assimilates and the necessity to use starch reserves to support the current needs.

The calculated figures in the last row of Table 1, present the gap between the actual assimilation of the avocado tree and its assimilation potential. Orchardists must be aware of this gap as well as of the differences between the avocado tree monthly dry matter production and utilization.

Every measure that will be taken in the future towards reduction of those gaps may result in increased avocado yields.

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