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Methods of Foliar Surface Determination along the Ontogenetic Cycle on Apple Trees

Valerian BALAN

Agrarian State University of Moldova, 42 Mircesti Street, Chisinau, MD 2049, Moldavia; v.balan@uasm.md

Abstract

This study aimed at determining the evolution of foliar surface in different types of annual branches of apple using different methods of foliar surface determination. The investigations were carried out in the intensive orchard of Didactic Experimental Station "Criuleni", Moldavia. The observations were made on the cultivar 'Golden Delicious' grafted on an M4 rootstock, and planted at 5 x 3 m distances, along the main four periods of ontogenetic cycle (growth, growth and fructification, fructification and growth, fructification). The trees were formed by the free growing palmette type. The leaf surface area was determined for all trees considered through measuring and numbering. In order to determine the dimension of the foliar surface, all types of annual shoots were measured. In addition, the quantity of leaves on the annual shoots and on the spurs was determined. Using the existing data, the leaf surface area for tree and area unit was calculated. Leaf area in the trees, during ontogenesis, was 3.26-29.9 m^2/tree, respectively 2.1-10.92 m^2/tree on the shoots and 1.16-23.7 m^2/tree on the spurs, spears and old spur systems.

Keywords: leaf surface area, species, leaf, spur, fruit bearing formation, annual shoot

Introduction

Fruit growing with respect to its research activity, is based on a range of research methods aiming at the photosynthetic system of fruit trees. To determine the leaf area of the trees, different methods were suggested, e.g. the planimetric method, gravimetric method, digital camera, photovoltaic panel, water sensitive paper, the calculation method (Nichiporovich, 1961; Casassa *et al*., 1985; Ovsianikov, 1985; Devyatov, 1986; Hrušková and Paulen, 1998; Moyseychenko, 1988; Asada, 1989; Yuan K. *et al*., 2006; Curiel-Rodríguez *et al*., 2007; Draganescu *et al*., 2008; Igathinathane *et al*., 2008; Demirsoy, 2009; Banaj *et al*., 2010; Spann and Heerema, 2010). In order to achieve this objective, it was sought to establish a complete working methodology that can provide accurate and useful data for calculating leaf area and assess the degree of its influence on tree productivity (Balan, 1983; Cimpoies, 2000). These methods consist of determining the values of indicators, with respect to thoseindicators that lead to the calculation and distribution of leaf area in the crown of the tree.

Materials and methods

Studies and research on the establishment of biological indices for determining leaf area were conducted during ontogenesis (1989-2005), on the field of the Didactic Experimental Station "Criuleni", Moldavia, in an intensive apple plantation.

The observations were made on the cultivar 'Golden Delicious' grafted on an M4 rootstock, and planting at 5 x 3 m distances, along the main four periods of the ontogenetic cycle (growth-third year, growth and fructification-7th year, fructification and growth-11th year, fructification-17th year). The crown shape of trees was a flattened palmette mixed type.

During the growing season, many observations, measurements and determinations which were later supplemented by laboratory tests were made. Leaf surface was determined separately on the shoot leaves, dards, spurs, and bourse. Total leaf area of a tree is calculated based on the number of leaves and the average area of a leaf. Findings of photosynthetic potential and growth of trees were based on the average and cumulative length of the annual branches and the number of fruits and fruit bearing branches. In autumn, after the leaves had fallen, all annual branches over 4-5 cm length were measured and then the tree growth was calculated. The annual branch nodes and their density were also determined.

The quantity of fruit was established after physiological fruit drop and two weeks before harvesting. For the 'Golden Delicious' variety, one fruit remains after the physiological fruit drop in each rosette of leaves. Therefore, the number of leaf rosettes on the tree was determined by the correspondence between the number of fruit harvested and spurs (branches budding fruit). Particular attention was granted to individual development of trees, the vegetation status of leaves, harvesting, preservation and preparation of samples for analysis. Making the experiment requires the following steps:

• **Choosing trees.** In order to determine the leaf area of the crown, three typical trees selected that were normally developed, without faults, in each variant. The internal

structure of the crown, height and diameter of these trees were determined. Measurements with pine slats or wire cane were performed. The internal structure of the crown through the method of branching and the skeleton and semi skeleton garnishing was determined.

• **Identification of control branches.** To examine the surface of leaves, typical branches were chosen and marked which will undergo dynamic measures. Records covered the entire process of ontogenetic development and the annual cycle and highlighted the main phenophases of growth and fruition. After leaf fall, measurements of total increases were performed on control trees.

• **Choosing shoots.** In order to correctly characterize the leaf surface, the branch extending shoots semi skeleton with the morphological characters of leaves that were fully developed were taken into account. For this purpose, shoots located at a height of 1.5-1.7 m from the soil surface in the eastern part of the crown were considered, as well as branches that were well exposed to sunlight, as they were marked with colored plastic tags. This allowed the analysis of these processes to be quick and very close to environmental conditions.

• **Election spurs.** In order to estimate the leaf area of rosette, spurs with the greatest opportunities for differentiation of fruit buds, grown in the Eastern periphery of the crown under conditions of sufficient light were chosen.

• **Harvesting the leaves.** In order to determine leaf surface, only the middle to top leaves of the shoot, located from the position of 5th and 6th, of uniform size and normal development and normally developed rosettes are usually considered. Immediately after harvesting, leaf examination in the laboratory on fresh material was performed. To avoid dehydration during transport leaves collected from the field on paper sheets and cellophane bags were isolated.

• **Determination of lamina surface.** Leaf area was determined separately for shoots and spurs using 200 leaves for each category by means of the gravimetric method. In the case of gravimetric analysis of the leaf surface, a representative sample of 100 leaves was collected and weighed. Then stalks were cut, weighed and their rate of leaf mass measured. From lamina leaves, through hollow drill with a diameter of 0.8 to 1.2 cm, a sample containing 100 rounds was collected and then weighed.

Results and discussion

Tab. 1 introduces data referring to the evolution of the lamina and petiole mass and the lamina surface during growth and fructification of the trees on the shoots of the 'Golden Delicious' apple cultivar. The mass of a petiole leaf on the shoots was 8.86-11.02 % of total leaf mass. During the fructification period of the trees, leaf stalk weight of the shoot is higher compared to the growth period of the ontogenetic cycle.

Lamina area on the shoots varies from 33.47 cm^2, during the period of fructification up to 44.31 cm^2 during the growth period of the trees. Number of developed and undeveloped leaves on the spurs varies from one period to another depending on the age of the trees. During the fructification period, from 103, the average leaf number on the spurs was only 52 developed leaves. During the growth period of the trees, the average leaf number on the spurs was 93, while the number of undeveloped leaves number was 15. The analysis of the data presented, shows that during the ontogenesis cycle the 'Golden Delicious' showed significant differences between developed and undeveloped leaf numbers. Lamina surface analysis obtained on the shoots and on the spur, during the ontogenesis cycle, shows that the largest area of the lamina was recorded during the growth of trees (42.31 cm^2). In the fruition period, the surface of lamina was 35.95 cm^2 on the spur and 33.47 cm^2 on the shoots. In the fruit-bearing period, the surface of lamina on the spurs was 20.92 cm^2 which demonstrates that the photosynthetic potential of the plantation in the fruition period of the ontogenetic cycle gradually decreased.

In determining leaf area per tree, a special attention was granted to the method of calculating the elements measured in the rosettes of leaves and annual branches cumulate length (Tab. 3). During ontogenesis, the growth potential is initially very high and gradually decreases with age. Tree growth is enhanced during growth and fructification (74 m / tree) and fructification and growth period

Tab. 1. Method for determining the mass and the average area of leaves on shoots in 'Golden Delicious', grafted on rootstock M4

Specification	Units	Period of ontogenetic cycle (the stage life of trees)			
		Growth third year	Growth and fructification, 7th year	Fructification and growth, 11th year	Fruiting, 17th year
Number of leaves	pieces	100	100	100	100
Leaves and petiole weight	g	87.74	77.86	81.33	73.91
Leaves without petiole weight	g	79.76	70.71	72.7	65.76
The share of petiole mass in the leaf mass	%	8.86	9.18	10.6	11.02
Mass to 100 washers	g	2.13	2.27	2.23	2.22
Area of 100 washers	cm^2	113	113	113	113
Surface of the lamina	cm^2	42.31	35.2	36.84	33.47

Tab. 2 Method for the determination of the mass and the average area of the leaves on the spurs in the 'Golden Delicious' tree, grafted on rootstock M4

Specification	Units	Period of ontogenetic cycle (the stage life of trees)			
		Growth, third year	Growth and fructification, 7th year	Fructification and growth, 11th year	Fruiting, 17th year
Number of spurs review	pieces	15	15	15	15
Number of developed leaves on spurs	pieces	78	59	60	52
Number of undeveloped leaves on spurs	pieces	15	30	47	51
Average number of leaves on spurs (2+3)	pieces	93	99	107	103
Average number of leaves on rosette (4:1)	pieces	6.2	6.6	7.13	6.86
Leaves with petiole weigh	g	36.7	22.35	28.27	21.74
Leaves without petiole weigh	g	32.77	19.82	24.93	19.07
The share of petiole mass from leaf mass	%	10.71	11.32	11.81	12.28
Weight to 100 washers	g	1.68	1.53	1.48	1.4
Area of 100 washers	cm^2	113	113	113	113
Surface of the lamina	cm^2	35.95	25.16	26.33	20.92

(65 m / tree) and becomes slow and prolonged in the period of fructification (44 m / tree).

Leaf density per linear meter of branches does not depend on the age of the trees (39.4-42.1 pieces per meter). In determining the cumulative length of annual branches, the number and size of leaves, foliar surface was calculated. Thus, leaf area during the growth period was 2.1 m^2/ tree and 10.92 m^2/ tree in growth and fruit-bearing period of trees. In the following two periods of tree life, leaf area on the shoots decreases gradually reaching 6.2 m^2/tree.

The research undertaken (Tab. 3) shows that the amount of fructification branches were influenced by the age of the trees. During the growth and fruit-bearing period of the tree the differences between the number of fruit-bearing branches with flower buds for the current harvest (spears, fruiting spur) and fruit branches without flower buds are to be observed, thus ensuring the fruit for next year (spurs), which were lower and for the following age periods they were higher. The number of spears and old spur system is directly proportional to the productivity

Tab. 3. Method for determining foliar area in 'Golden Delicious', grafted on rootstock M4

Specifiction	Units	Period of ontogenetic cycle (the stage life of trees)			
		Growth, third year	Growth and fructification, 7th year	Fructification and growth, 11th year	Fruiting,17th years
Length of the combined annual branches	m/tree	12	74	65	44
Average number of leaves at 1 m branch	pieces	41.45	41.92	39.4	42.1
Number of leaves per annual branches (1x2)	pieces	497.4	3102.08	2561.0	1852.4
Surface lamina to the shoots	cm^2	42.31	35.2	36.84	33.47
Leaf area on the annual branches (3x4)	m^2/tree	2.10	10.92	7.95	6.2
Share of foliar surface on annual tree branches	%	64.42	51.95	30.69	20.74
The number of spears and older spur system (fruit harvested)	pieces	0	204	197	260
The number of spurs	pieces	52	405	759	1392
The number of rosettes of leaves (7+8)	pieces	52	609	956	1652
Average number of leaves in the rosette	pieces	6.2	6.6	7.13	6.86
The number of leaves on spears and older spur system (7x10)	pieces	0	1346.4	1404.61	1783.6
The number of leaves on spurs (8x10)	pieces	322.4	2673	5411.67	9549.12
The number of leaves on rosette (9x10)	pieces	322.4	4019.4	6816.28	11332.72
Surface of lamina on the rosette	cm^2	35.95	25.16	26.33	20.92
Surface of the leaf rosettes on spears and older spur system (11x14)	m^2/tree	0	3.38	3.70	3.73
Surface of the leaf rosettes on spurs (12x14)	m^2/tree	0	6.72	14.25	19.99
Surface of the leaf rosette (13x14)	m^2/tree	1.16	10.1	17.95	23.7
Share of rosettes on tree foliage area	%	35.58	41.95	69.31	79.26
Leaf area on tree (5+17)	m^2/tree	3.26	21.02	25.9	29.9

of the trees, namely 204 pieces per tree during the growth and fructification period and up to 260 pieces per tree during the fruit-bearing period of tree. The number of spurs on the trees increased gradually from 52 pieces per tree during the tree growth period; and reached a maximum of 1392 pieces per tree during the fruit-bearing period of the tree. The analysis on the foliar surface of rosettes shows that the highest values were registered during the fructification and growth period of tree (17.95 m^2/ tree) and fructification period of trees (23.7 m^2/tree).

Leaf area in the trees changes depending on the age and productivity of the trees. The research led to the conclusion that in the growth period most leaf surface 2.1 m^2/ tree (64.42%) is formed on the shoots and only 1.16 m^2/ tree (35.58%) on the spurs, spears and old spur systems. In the following life periods of the trees, leaf area on tree exhibits higher values on the spurs, spears and old spur systems and lower on the shoots. Thus, during the fructification period of the trees, the leaf surface of the shoots is 20.74% (6.2 m^2/tree) and on the branches of the fruit 79.26% (23.7 m^2/tree).

Conclusions

A full working methodology was established after completing this experiment, based on accurate data useful for assessing the photosynthetic potential in apples. At the same time, there was a broad investigation of the methodologies used to indicate the biological material suitable for the experiment. The number of fruit at harvest (spears, old spur systems) and spurs can be used to determine the number of rosettes of leaves, for example. Furthermore, knowing the number of rosettes of leaves, one can determine the average number of leaves in the rosette and leaf area of rosettes, as well as the foliar surface of rosettes. Foliar surface size and growth of shoots showed that shoot size was not the basic criterion in order to assess foliar surface, but total value of the annual growth was. Foliar surface was examined in the light of the changing proportions of different types of leaves. Data presented drew attention to essential changes in the percentage of participation of leaves formed on shoots, spurs, spears and old spur systems, in the composition of the leaf device. The share of the foliar surface on annual tree branches during the growth period shows that most of the leaf area, 64.42%, is formed on the shoots and only 35.58% on the spurs, spears and old spur systems. In the following life periods of the trees, the leaf area on trees show higher values on the spurs, spears and old spur systems and smaller ones on the shoots. Thus, during the fructification period of tree, the leaf surface of the shoots is 20.74% and on fruit branches 79.26%.

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