

APPLE TREES PLANTATION STRUCTURE

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Abstract: Within high density plantings were studied the main factors of the growing, photosynthetic activity and the arrangement of the foliage. We established the dependency between the potential of the planting productivity and the parameters of the crown in specific ecological conditions. For modern high density orchards the most efficient parameters of the foliage area, as a photosynthesis system, are: the height of the foliage area between 2.3 – 3.5 m; the width at the basis of the crown 1.5 – 2.5 m with gradual decrease to top to 0.8 – 1.2 m; the inclination angle of the lateral plane of the row 12 - 13°; the angle which unites the tops and the bases of the crown of nearby rows is equal with the latitude of the locality. With such parameters of the foliage area the utilisation of the surface under the crown projections, as index of possible capture of solar radiation, achieves 52 - 60 %, the lateral surface of the crowns, which captures the direct and dispersal radiation 17200 – 19800 m²/hectare, the volume of the active foliage area 12200 – 18100 m³/hectare.

Key words: apple tree, rootstock, foliage, solar energy, plant density, integrated production.

INTRODUCTION

Apple orchards are a long term investment, so it is essential to choose tree spacing and a production system that will make best use of land and capital to produce fruit. Potential hectare yields depend on the volume of bearing wood maintained in an orchard. Increasing the number of trees per hectare is one way to increase the volume of bearing wood and thus yield. Yield can also be increased through proper pruning, training, and management. Growers must consider their ability or inability to manage a particular production system (1, 3, 6, 10).

The renovation of a commercial orchard should require a reflection concerning the technical, economical and ecological aspects being derived from the choice of the training system (5). As a global analysis, the orchard system takes into consideration precise aims such as yields, precocity, quality and steadiness of the production, conformity to the requirements of the integrated production, mechanization and rationalization of the manual work (3, 10, 11).

MATERIAL AND METHODS

The research for study and development of optimum parameters structure of the fruit plantings of leading sorts of apple (the Slava peremojtiam, Kalvili snow, Renet Simirenko, Richared Delicious, Winter Banana, Golden Delicious, Mantuaner, Jonathan, Idared, Wagener prize, Starkrimson), grafted on rootstocks M 4, MM 106 and M 9 at the Department Fruit growing State Agrarian University of the Moldova, were started since 1973.

The following parameters of the plantings structure were studied in different combination: distance between rows - 3,5; 4,0; 4,5; 5,0; 5,5 m and between trees in a row - 2,5; 3,0; 3,5; 4,0; 4,5 m; the width in the crown - 1,0; 1,5; 2,0; 2,5; 3,0 m; the height of the crown - 2,0; 2,5; 3,0; 3,5; 4,0 m. The experiences were repeated three times. The direction of the rows from north to south. The numbers of registered trees in each variant are 24. The trees are formed on type of liberally rising fan-shaped espalier (palmetto) and liberally rising spindle of the bush.

At the basis of the studies are methodological indications for the establishment of orchards with high productive structures, the evidence and the control of the main indices of photosynthetic productivity, the study of the biological rotation in phytocenosis.

The main indices of the geometric structure and the productivity of the fruit plantings were studied in S.D.E. "Kriuleni" and "Ketrosu". Topsoil of the fruit plantings is presented by powerful chernozem on light loam. The contents of humus in layer of active soil (0 - 100 cm) in chernozem constitutes 1,36 - 3,22%. In accordance to content of the compounds for plants the chernozems are provided well with potassium, satisfactory with nitrogen, insufficient with phosphorus.

RESULTS AND DISCUSSIONS

Were determined the main indices of plantings structure: system of the arrangement of trees and rows; the size and the form of their elevated part; the degree of utilisation of planting surface; the area of lateral surface of the crowns and the area illuminated by direct radiation, area of the foliage; foliage index and the arrangement of the foliage in space.

The specific particularity of the crowns is their biological and physiological distinction, such as conditions of illumination, feeding, water and other factors in different areas of the crown. The divers area of the crown determines the area of the foliage and its physiological condition, the quantity and the quality of the crop. Therefore, at the elaboration of system of setting up and pruning of the trees it is necessary that the crown of tree to be completed by productive branches and to be well.

The obtained data shows essential differences in irradiation of different parts of the crown during a day depending on structure. In the morning (9.00 – 11.00 a.m.) on the height of 1 m from the soil more solar energy is captured on the east side of the crown, less – in the centre of the crown and small part of solar energy is captured on the west side. At the height of 2 - 3 m from the soil are the same regularities, as the height of 1 m, but the differences of sides are less significant. With the increasing of intensity of solar radiation (11.00 a.m.) is improved the irradiation of all sides of the crown, especially the east side. At the noon (13.00 p.m.), like in other times, the irradiations of the row sides increase in accordance with the increasing of the height from the soil. In that time the zone along the central axis of the row and the lower part of the crown were less irradiated, thanks to increase of thickness of foliage area, though which penetrates physiological active radiation.

In the afternoon (15.00 - 17.00) the highest intensity of solar radiation was noticed on the west side of the crown. The east and central parts of the crown are irradiated approximately equally. Thereby, the irradiations of inside parts of the crown increase in accordance with the rising of the height from the soil. In a day in the lower part of the crown penetrates only 27 - 28 % of photosynthetic active radiation (R. A. Ph.) Therefore, the assimilation area of the lower part of crown receives enough R. A. Ph. for normal function of bearing organs [5, 11]. For this it is necessary that the adequate side of the crown to be at least three hours per day in the conditions of direct solar radiation [1].

The analysis of experimental data shows, at the direction of the rows on meridian, the lower part of the east side of the crown will be irradiated by direct solar energy more than three hours in the morning and more than three hours in the afternoon for west side. The study of the particularities of forming and arrangement of the leaves and reproductive organs in the crowns of the tree has great importance for elaboration of optimum productive sizes and forms of the crown. Brought given (Table 1) show that beside 7 - 17-years old trees on 1 - 4-years old wood have 68,2 - 97,8% of leaves and 93 - 100% fruits.

Table 1
The arrangement of the foliage area and the fruits on different branches depending on sort and age of the tree (%); the scheme of planting 5x3 m, form of the crown spindle of the bush, Gratiesti

Sort	Area of the foliage		The quantity of fruits	
	The age of the branches			
	1-4	5-6	2-4	5-6
Rootstocks MM 106, age tree 7 years				
Golden Delicious	94,8	5,2	-	-
Idared	88,6	11,4	-	-
An average	91,9	8,1	-	-
Rootstocks M 4, age tree 17 years				
Slava peremojtiam	83,0	17,0	95,9	4,1
Kalivili Snow	89,2	10,8	94,2	5,8
Mantuaner	71,4	28,6	96,3	3,7
Jonathan	68,2	31,8	97,6	2,4
Renet Simirenko	78,3	21,7	93,0	7,0
Wajener price	97,8	2,2	100,0	-
An average	82,7	17,3	96,1	3,9

For the elaboration of optimum parameters of crown are studied 4 – year's old branches (Table 2). Was established that the length of the productive part of the semi skeleton branches is 114,0 - 205,4 cm at 12 – years old trees and 117,3 – 218,7 cm at 17 – years old trees. Therefore, the depth of the productive part to 4 – years apple tree, in horizontal plan to 12 – years old tree is 85,5 – 154,0 cm, but 17 – years old tree – 92,7 – 164,0 cm. The length of the central leader of four years branches is proportional with the power of the growing.

Table 2
The length of the central leader of the 4-year old branches of apple trees and their projection on the surface of the soil (cm); rootstocks M 4, the scheme of planting 5x3 m, form of the crown liberally rising spindle bush, Gratiesti

Sort	Age tree			
	12 years		17 years	
	Length of the central conductor	Length to projections	Length of the central conductor	Length to projections
Slava peremojtiam	142,8	107,1	154,7	115,9
Kalivili Snow	205,4	154,0	218,7	164,0
Mantuaner	146,0	109,5	117,3	87,9
Jonathan	170,0	127,4	132,7	99,5
Renet Simirenko	203,6	152,7	212,0	158,9
Wajener price	114,0	85,5	123,3	92,7
An average	163,6	122,7	159,7	119,8

The mentioned regularities in the evolution of bearing wood of the crown have served as a reference to consider that the width of the crown must not be more than 171 – 328 cm in order to use only one order of ramification of skeleton branches for rationally utilisation of R. A. Ph. Concerning to the length of crown from which depends the density of the trees arrangement, it mustn't be more than 250 – 350 cm, because further increasing of the crown size lead to the forming of the unproductive zone at the basis of the main branches. Crop capacity is determined by the volume of the productive part of the crown calculated to the unit of orchard area. Therefore, at calculation of optimum size of the crown it's important to determine the productive volume of the crown (Table 3).

Table 3

The main phytometric features of the foliage structure in plantings of the apple trees Golden Delicious, grafting on rootstock M 4 (at the average on age period), form of the crown liberally-rising palmette S.D.E. "Kriuleni"

The scheme planting (m)	Utilisation of the area (%)		Total contour surface of the crowns (thous. m ² /hectare)		Volume of active foliage (thous. m ³ /hectare)	
	Growing and fruit- bearing	Fruit- bearing	Growing and fruit- bearing	Fruit- bearing	Growing and fruit- bearing	Fruit- bearing
4,5x4,5	32	58	17,2	19,2	6,7	15,7
5x4	3,3	56	20,6	17,8	4,5	15,8
5,5x3,5	31	52	10,9	17,2	6,4	16,5
5,5x3	38	53	10,6	18,1	9,2	18,1
4x4	37	58	23,4	19,5	9,8	14,8
4,5x3,5	39	60	19,5	19,1	6,8	15,4
5x3	37	55	12,0	18,4	7,3	16,9
4,5x3	45	58	13,6	18,6	8,7	15,3
3,5x3,5	51	59	24,2	19,8	10,0	9,0
4x3	44	56	14,6	18,7	8,6	12,2
4,5x2,5	44	55	13,3	17,9	8,4	13,6

The degree of utilisation of orchard area under the projection of the crowns, as factor of the possible absorption of direct solar radiation, during the period of growing and fruit bearing constitute from 3,1 to 5,1 thousand m²/hectare and reaches the maximum values (52 – 60 %) in the period of complete fruit - bearing. The theoretical calculations on the example of plantings with different types of the crown and the density of planting, permitted to affirm that the area of utilisation of orchard under the projection at the crowns must be 80 – 85 % and more [2, 7].

Thereby, the use of palmette crowns with trapezium cross – sections showed that keeping of minimum permissible clear spaces between crowns (1,8 – 2 m) which ensure the possibility of mechanisation of technological processes and optimum penetration of solar radiation inside the crown, the width of the crown decreases more than the distance between rows [3,4]. Therefore, the width of the foliage of palmette crowns must be equal or more than distances between crowns. Otherwise, the decreases of distances between rows lead to the reduction of the productivity on unit of orchard area [11].

A very important factor of the structure of fruit plantings which determine the possibility of using of photosynthetic solar radiation is the area the crowns irradiated by direct radiation. In young orchards the absorption surface is 10600 – 24200 m²/hectare. Slowly is utilized the surface and the space e in the case of shaping of liberally rising palmette, in rarefied orchards, as the direction of the main branches only along the row reduces the growth

of the crown volume. In the period of fruit - bearing the absorption surface of crowns is equal in all variants of the experience.

An important factor of estimation of orchards productivity could be the volume of the productive part of the crown. In young orchards the reduction of row spacing and distances between trees in a row lead to the increase of productivity potential of the orchards, which achieve maximum (10.000 m²/hectare) on the scheme of planting 3,5 x 3,5 m. In the fruit - bearing period the productive part of the crown depends on row spacing and less on distances between trees in a row. So, the increase of row spacing from 4 to 5,5 m by the distances of 3 m between trees in the row, the area of the crown grew from 12200 to 18100 m²/hectare or with 48,4 %, but in the case of increasing the distance in a row from 2,5 m to 4,5 at row spacing of 4,5 m, the volume of the crown grew from 13600 to 15700 m³/hectare or only with 15,4 %.

A big interest presents the argumentation of optimum parameters of the crown which permit to capture the maximum R. A. Ph. It's obvious, that the irradiation with direct sunrays will depends by the angle inclination of lateral plane of the row and angle which unite the tops and the bases of crowns of adjacent rows [8]. At calculation of optimum parameters of the crown it's necessary take into account, that in the north hemisphere during vegetation period (June – august), sun rays fall under an angle which is equal with geographical latitude of the area in the morning (8.00 – 8.30) and in the afternoon (15.30 – 16.00). Therefore, in the case of row spacing on meridian, the basis of the crown will be in the conditions of direct solar radiation more than 3 hours in the morning (east side) and more than 3 hours in the afternoon (west side).

Thereby, the brought given permitted to examine the fruit planting as optical system, which is able to capture maximum solar energy in the concrete conditions of growing through distances of planting, size and the form of the crown (Figure 1). Therefore, in the case of calculation of optimum size of the crown it's important to determine the distances between tree rows. Since the distance between rows (**L**) depends on the height (**H**) and the width of the lower part of the crown (**B**), the angle of inclination (**α**) of row plane and the angle which unite the top and basis of the crowns of adjacent rows, according to latitude of the locality (**φ**) could be express by the equations:

$$\begin{aligned} L &= H \operatorname{tg} \varphi - H \operatorname{tg} \alpha + B \\ L_1 &= 2l \sin \beta - 0,5 \end{aligned}$$

The essence of the method consists in the parameters of the foliage structure in the plantings such as the height and width of the crown, the angle of inclination of row plane and the distance between crowns of adjacent rows correlate with the irradiation of the crown according to locality from 8.30 to 15.30 hours.

CONCLUSIONS

Theoretical and experimental studies, the analysis of the literature and the production experience on intensive cultivation of apple tree permit to establish that the most efficient optimum parameters of structure of the plantings in the conditions of the Republic of Moldova are the following schemes of planting, size and form of the crowns:

On soil areas with high and middle level of the fertility to place dwarf sort-rootstocks combinations. Semi dwarf sorts, grafted on dwarf rootstocks (M 9, M 26) and dwarf sorts, grafted on semi dwarf rootstocks (M 4, MM 106) are placed on the scheme 3,5 – 4 x 1,6-2,8

m. In such orchards the optimum width of the crown at the basis is 1,5 - 1,8 m with gradually decreasing to 0,8 - 1,2 m and the height of the foliage of 2 - 2,5 m.

On the areas with low level of fertility of the soil it's reasonable to place semi dwarf sorts of the apple tree, grafted on semi dwarf rootstocks (M4, MM106).

The scheme of planting: 4 - 4,5 x 1,7 - 3,4 m. The height of the foliage till 2,5 - 3 m, the width at the basis 1,5 - 2 m with gradually decreasing to the top to 0,8 - 1,2 m.

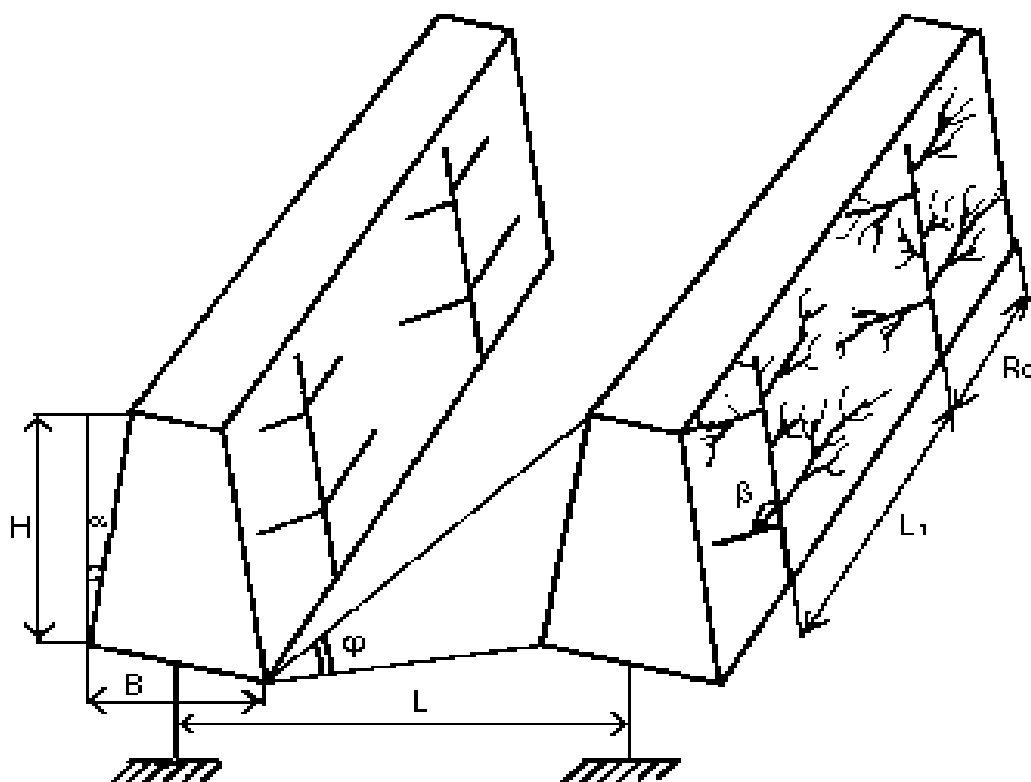


Fig. 1. The parameters of the plantation structure

- L – Between rows spacing, m
- L₁ – In-row tree spacing, m
- H – Height of the crown, m
- B – Width of the lower part of the crown, m
- l – The length of the skeleton branches, m
- α – The angle of inclination of row plane, °
- φ – Latitude of the locality, °
- β – The angle of inclination of the skeleton branches, °

On shallower soils area with low level of fertility it's more efficient to place vigorous sort – rootstocks combinations. The vigorous sorts, grafted on semi dwarf rootstock M4, semi dwarf and dwarf grafted on vigorous rootstocks (the seedlings of cultivation sorts) are placed with the distances between rows of 5 m and in the row of 2,3 - 2,5 m gradually decrease to the top to 1 - 1,2 m.

Further increasing of the productivity of apple orchards with the mentioned phytometric features of the foliage, it's possible at the expense of utilisation of high productive sort – rootstocks combinations, optimum density of the trees, forming and pruning of trees, optimisation of photosynthetic activity, and mineral nutrition and water regime of the plants.

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REZUMAT

STRUCTURA PLANTAȚIILOR DE MĂR

În cadrul plantațiilor de măr cu densitate mare la unitatea de suprafață au fost studiați principalii factori de creștere ai pomilor, activitatea fotosintetică și particularitățile foliare ale pomilor. S-a stabilit dependența potențialului productiv al pomilor de diferiți parametri ai coroanei pomilor în condiții concrete de mediu. Pentru livezile moderne, cu mare densitate de plantare, cei mai eficienți parametri ai zonei foliare, ca sistem fotosintetic, sunt: înălțimea zonei foliare, între 2,3-3,5 m, lățimea la bază a coroanei de 1,5 - 2,5 m, cu o descreștere gradată până spre vârf de până la 0,8 - 1,2 m; înclinarea unghiului planului lateral al șirului de 12 - 13°, unghiul care unește vârfurile și bazele coroanelor șirurilor învecinate, egal cu latitudinea localității. Cu astfel de parametri ai zonei foliare, gradul de utilizare al suprafeței de proiecție a coroanei, ca indicator al captării radiației solare ajunge la 52 - 60 %, suprafața laterală a coroanei care captează radiația directă și dispersată la 17.200 – 19.800 m²/hectar, iar volumul ariei foliare active la 12.200 – 18.100 m³/hectar.