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The Basis for Defining a Model of Ecological Functions of the Organogenesis in Fruit Crops

- Review paper -

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Abstract: The paper presents an analytical approach in defining the organogenesis cycle as a biological basis for modelling ecological functions of growth and development of fruit crops. The interpretation of the organogenesis cycle on the algorithmic basis and the data on ecological factors the computer accessed via the Meteorological Centre made possible the defining of a model of ecological functions of the organogenesis cycle in fruit crops. The model developed in this way, on the basis of average values of several-year functions and recorded variations of ecological parameters within each defined stage and substage, would increase its preciseness in time, concerning the estimation of the moment of their onset or the expected degree of productivity from ecological or biotechnological aspects. The model can also be developed as a basis for integrating all elements of the technological process (protection, nutrition, etc.) in a highly intensive fruit growing.

Key words: Fruit crops, modelling, organogenesis.

Introduction

The analysis of the life cycle of growth and development of agricultural crops, by division into the appropriate number of stages or substages, ***Kuperman***, 1968, ***Isaeva,*** 1978, ***Mićić***, 1993, or by numeration (by the introduction of uniform codes) of the typical phenophases and microphenophases during development, ***Zadoks et al.***, 1974, ***Tottman*** and

Makepeace, 1979, ***Tottman***, 1987, ***Lancashire et al.***, 1991, represents two aspects of the same approach to this issue. The determination of characteristic and analytically complete processes in the differentiation of organs and tissues in the annual cycle of plant organogenesis represents the basis for defining these two approaches.

The precise determination of typical processes in the differentiation of organs and tissues, as well as, the determination of the time of their initiation and dynamics, represent a basis for developing the algorithm of the organogenesis cycle of the plants studied, ***Mićić*** and ***Djurić***, 1994. This approach enables an integrated study of the effects of various factors, analysed as a treatment of the current stages of the organ and tissue differentiation. The precise determination of certain effects on the current courses of differentiation, and then a clear definition of their response in productivity of the organogenesis cycle, enable the development of a model for broader investigations within biotechnological sciences.

The objective of this paper is to present the organogenesis cycle on the algorithm base as the biological basis for defining ecological functions model.

The Fruit Crop Organogenesis Cycle

On the basis of previous studies of the organogenesis cycle in various fruit crops, ***Mićić*** and ***Kurtović***, 1987, ***Mićić et al.***, 1988, ***Djurić*** and ***Mićić***, 1988, 1989, ***Radoš et al.***, 1989, ***Mićić*** and ***Djurić***, 1989, 1994, ***Djurić et al.***, 1992, ***Mićić***, 1993, all characteristic stages in the differentiation of their organs and tissues in the annual cycle have been classified. According to this classification, the sequence and dynamics of their occurrence were presented graphically as the basis for defining the organogenesis cycle on the algorithm base, ***Mićić*** and ***Djurić***, 1994.

The organogenesis cycle expressed on the algorithm base represents a model for developing software which will take over meteorological parameters from the computer at the Meteorological Centre and form the database for each stage and substage. The obtained database enables the calculation of mathematical functions of the recorded meteorological parameters, i.e. the development of an ecological functions model of the defined organogenesis cycle in fruit crops.

The organogenesis cycle in fruit crops grown in our regions, observed integrally as a certain number of irreversible steps in organ and tissue differentiation, occurs in the following stages and substages:

Stage I - formation of new undifferentiated meristematic domes of the tree and seed.

Depending on fruit species, this stage has the following substages:

Ia_0 - formation of meristematic dome of the seed plumule;
Ia_1 - formation of primary meristematic dome in the leaf axil of new vegetative tree growths;
$Ia_{1'}$ - division of primary meristematic dome and formation of lateral meristematic domes of the nodes (the basis of collateral and serial buds).

Stage II – formation, differentiation, growth and development of vegetative tree organs.

Depending on fruit species, this stage has the following substages:

IIa_0 - differentiation of vegetative buds of the tree – formation of winter vegetative buds;
IIa_1 - differentiation of vegetative buds of the rhizome;
IIa_2 - differentiation of vegetative buds of annual growth increment in strawberry;
IIa_4 - differentiation of vegetative organs of mixed buds;
IIa_5 - differentiation of vegetative organs of the mixed buds on the pseudostem of the rhizome;
IIa_v - differentiation of growth increment – characteristics of male inflorescence axes;
IIa_x - differentiation of growth increment – characteristics of female inflorescence axes;
IIb_0 - differentiation of meristematic dome after dormancy break – formation of nodes with leaf primordia;
IIb_1 - growth and development of shoots and leaf rosettes;
IIb_2 - growth and development of annual growth increment of the rhizome;
IIb_3 - growth and development of annual growth increment of the stem of the erect rhizome in strawberry;
IIb_4 - growth and development of the rhizome pseudostem;
IIb_5 - growth and development of the fructification growth;
IIb_6 - growth and development of the fructification growth of the rhizome pseudostem;
IIb_v - growth and development of male inflorescence axes;
IIb_x - growth and development of female inflorescence axes;
IIc_1 - termination of shoot growth by shoot tip abortion.
IIc_2 - anchorage of the annual growth increment of the rhizome.

Stage III – change in a meristem character: transition from a vegetative to a generative differentiation phase – the onset of differentiation of generative buds. A certain number of newly–formed vegetative buds passes into this stage of organogenesis.

This stage occurs in two substages:

IIIa - progamic phase of the transition of a meristem character from a vegetative into a generative stage of differentiation – the process of genetic programming of the transition of meristematic dome into a meristematic apex of the generative bud;

IIIb - the onset of morphological changes on the meristematic apex of generative buds.

Stage IV – differentiation of flower – inflorescence axes.

Depending on an inflorescence type, this stage occurs in the following substages:

IV' - differentiation of primary flower – inflorescence axis.
IV'' - differentiation of secondary flower – inflorescence axes
IV''' - differentiation of tertiary flower – inflorescence axes

Stage V – differentiation of floral primordia.

This stage has the following substages:

Va - differentiation of receptacle tissues (formation of the initial recess on the top of flower axis primordia);
Vb - formation of sepal primordia ;
Vc - formation of petal primordia;
Vd - formation of anther primordia;
Ve - formation of carpel primordia;
Vf - growth and development of the formed floral primordia until a certain degree of differentiation, necessary for the normal passing of dormancy period, has been reached .

Stage VI – differentiation of anther tissue, male archaesporial tissue and the process of microsporogenesis.

This stage has the following substages:

VIa - differentiation of archaeosporial tissue;
VIb - meiosis;
VIc - microgametogenesis;
VId - pollen development up to anther shedding.

Stage VII – differentiation of ovules, female archaeosporial tissue and the process of macrosporogenesis.

This stage has the following substages:

VIIa - formation of ovule primordia in the ovary locule;
VIIb - differentiation of pronucellar tissue and the integuments;
VIIc - differentiation of archaeosporial tissue and macrosporogenesis.

Stage VIII – macrogametogenesis and cytological formation of the egg apparatus ready for fertilisation.

This stage occurs in the following substages:

VIIIa - the first mitosis of the macrospore nucleus – binucleate stage of the embryo sac;

VIIIb - the second mitotic cycle – 4-nucleate stage of the embryo sac;

VIIIc - the third mitotic cycle – 8-nucleate stage of the embryo sac;

VIIId - cytological constitution of the embryo sac elements: the egg cell with synergids in the micropyle region, the three antipodal cells in the chalaza region and polar nuclei in the central part of the embryo sac.

Stage IX – flowering and fertilisation.

This stage has two substages:

IXa - flowering and pollination;

IXb - the progamic phase of fertilisation and fertilisation.

Stage X – zygote and early embryogenesis

Stage XI – embryogenesis (seed formation).

This stage has the following substages:

XIa - the globular embryo;

XIb - the heart–shaped embryo;

XIc - the torpedo–shaped embryo;

XId - young embryo (the formed primordia of the major organs and cotyledon);

XIe - mature embryo with formed cotyledons (resorbed endosperm, the the seed–coat colour change).

Stage XII – formation of physiologically mature fruit and its ripening

This stage has two substages:

XIIa - formation of physiologically mature fruit;

XIIb$_0$ - differentiation of the ovary tissue in the function of seed dispersal – fruit ripening;

XIIb$_1$ - differentiation of the receptacle tissue, involucrum etc. into the edible tissue formed in the function of seed dispersal.

The Presentation of the Fruit Crop Organogenesis Cycle on the Algorithm Base

The graphical analysis of the sequence in the onset and interrelationship, as well as, in the dynamics of occurrence and duration of the defined stages and substages represents the basis for algorithmic definition of the organogenesis cycle.

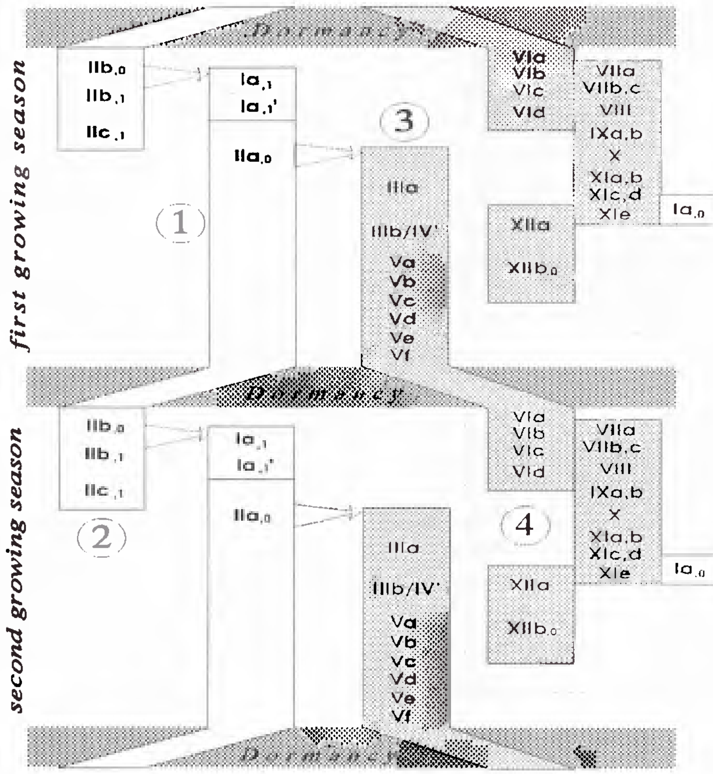

Figure 1. *Graphical presentation of organogenesis cycle in plum on the algorithm base*
Grafički prikaz ciklusa organogeneze šljive na algoritamskoj osnovi

An annual or a final cycle of organogenesis can also be observed as four subcycles: ① formation of new vegetative buds of the tree; ② growth and development of vegetative buds - formation of new growth; ③ differentiation of generative buds; ④ growth and development of generative buds – fruit bearing.

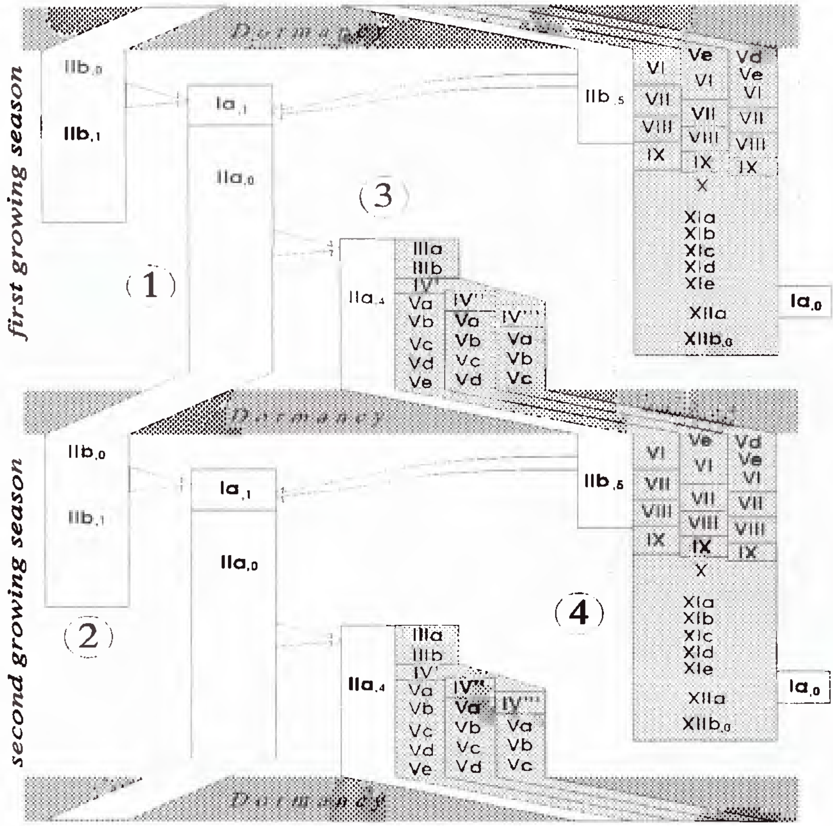

Figure 2. Graphical presentation of organogenesis cycle in apple and pear on the algorithm base
Grafički prikaz ciklusa organogeneze jabuke na algoritamskoj osnovi

The mentioned subcycles can occur simultaneously with differing levels of competitive relationships, depending on the differentiating organ, growth category and their location on the habitus.

The graphical analysis carried out shows that all 12 stages in the annual cycle of organogenesis occur during one growing season, but one complete or the final cycle from stages 1–12 occurs over 2–3 seasons, depending on fruit species.

Each stage or substage can also be developed into its own cycle of organ, tissue or cell differentiation (Figure 3). In this way, each new piece of information, each detail in the process of differentiation, or a new defined effect of a certain factor, can be additionally included as new steps, intersteps or complete algorithms into the integral algorithm of the organogenesis cycle.

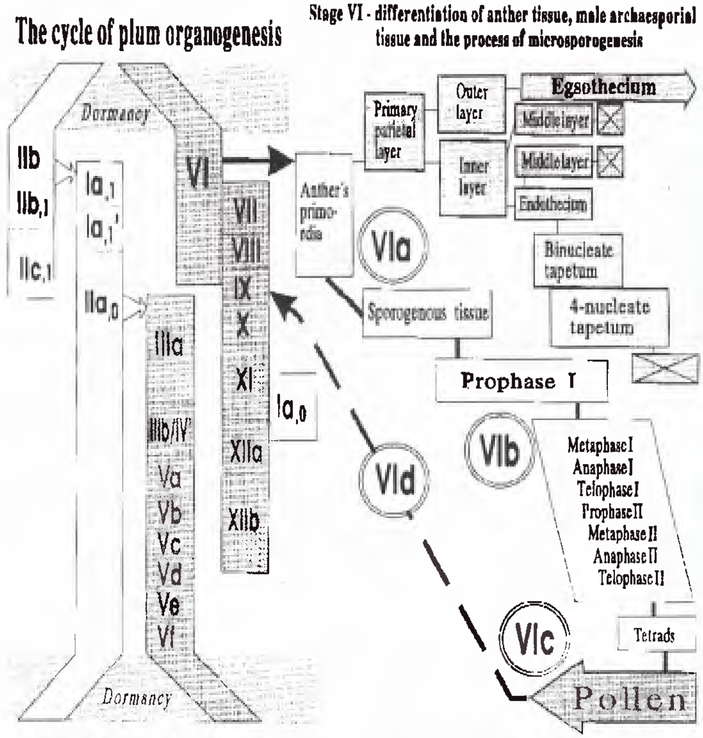

Figure 3. Development of each stage or substage into its own cycle of organ, tissue or cell differentiation
Razvoj svake etape ili podetape u sopstvene cikluse difernecijacije organa, tkiva ili ćelija

Possibility for Modelling Ecological Functions of the Organogenesis Cycle

On the basis of the developed algorithm base of the organogenesis cycle, as the biological basis for developing the ecological functions model, it is necessary to make software with the following possibilities: 1) formation of database of meteorological parameters; 2) base formation of the course of organ and tissue differentiation in the organogenesis cycle by communicating with the observer of the organogenesis cycle course; 3) calculation of mathematical functions and other elements of the model in order to find an answer about the current stage of differentiation, estimating the moment of the onset of the next or, in the defined treatment, the target stage of organogenesis, as well as, about other suggestions concerning planned or expected user's activities.

On the basis of the organogenesis cycle algorithm and the availability of meteorological data to the computer for formation database of meteorological parameters during each defined stage or substage, conditions necessary for the ecological functions model development in the organogenesis cycle have been created. The mathematical model of ecological functions for the processes of organ and tissue differentiation in the annual cycle of organogenesis on the basis of the average several-year functions of ecological parameters, gradually increased its preciseness in the estimation of the course of typical stages or expected degree of their productivity from the ecological aspect.

In this way, possibilities are being created for an integral study of the effects of all ecological parameters on the individual processes of organ and tissue differentiation in the annual plant development, as well as, of other aspects with the aim to affect this process.

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Osnova za definisanje modela ekološjih funkcija ciklusa organogeneza voćaka

- Revijalni rad -

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Rezime

Na osnovu algoritma ciklusa organogeneze i dostupnosti meteoroloških podataka računaru za formiranje baze meteoroloških parametara u toku svake definisane etape i podetape, stvoreni su neophodni uslovi za razvoj modela ekoloških funkcija ciklusa organogeneze. Matematički model ekoloških funkcija za procese diferencijacije organa i tkiva u godišnjem ciklusu organogeneze, na osnovu proseka višegodišnjih funkcija ekoloških parametara, bio bi sve precizniji u proceni toka karakterističnih etapa ili očekivanog stepena njihove produktivnosti sa ekološkog aspekta.

Na ovaj način stvaraju se mogućnosti za integralno proučavanje uticaja svih ekoloških parametara na pojedinačne procese diferencijacije organa i tkiva u godišnjem razvoju biljke, kao i drugih aspekata u cilju delovanja na ovaj proces.

Na osnovu izvedene algoritamske osnove ciklusa organogeneze, kao biološke osnove za izradu modela ekoloških funkcija, potrebno je uraditi softver sa sledećim mogućnostima: 1. formiranje baze podataka meteoroloških pokazatelja; 2. formiranje baze toka diferencijacije organa i tkiva u ciklusu organogeneze putem komuniciranja sa osmatračem toka ciklusa organogeneze; 3. izračunavanje matematičkih funkcija i drugih elemenata modela za dobijanje odgovora o tekućoj fazi diferencijacije, proceni momenta nastupanja sledeće ili u definisanom tretmanu ciljne etape organogeneze, kao i drugih sugestija u vezi planiranih ili očekivanih aktivnosti korisnika.

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