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The Analysis of the Management of Phytotron Arrangement and Variants

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Introduction

Phytotrons have many various purposes, the most common of which is manufacturing equipment used for growing of food crops in artificial conditions. Variety and sizes of this equipment and also electronic management peculiarities depend on consumers' different needs. Some consumers give priority to the quality of a plant (freshness), others emphasize acceptable and good quality and the rest put stress on the lowest price of the plants, having acceptable quality. This determines the places, means and management peculiarities of growing and complex composition of the electronic means used.

In order to work out a rational strategic direction, the economic aspects of the choice of phytotrons and their arrangement have to be analyzed.

The research of distance arrangement of phytotrons

Let us say that production can be defined in terms of two rates (Fig.1): quality (Q) and cost (C_k (Q)). The demand for the production of different quality can be defined in terms of function f(Q). For example, having chosen three classes and using optimization principles of their values [1], it is possible to calculate the demand of production of each class (N_1, N_2 and N_3). This will determine the types of phytotrons, their sizes and arrangement variants.

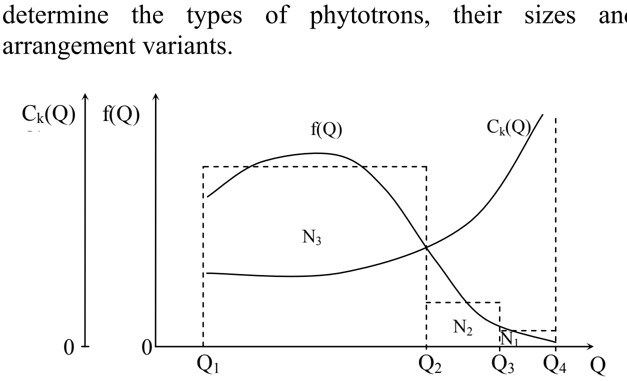

Fig. 1. The choice of the quality classes of production

It is seen from Fig. 1 that the sizes of phytotrons which provide the production of the highest quality for a consumer will be the smallest. They will have to be closest to a consumer in order the production would not go wrong while storing and transporting it. The amounts of the production transported will not be large. Therefore, the costs of its transporting will increase. Let us analyze the economic aspects of phytotron arrangement (Fig. 2).

Going far from a consumer (eg. at the distance l from a city), the rent of one unit of land area C(l) falls nonlinearly. This dependence can be expressed, for example, in the following way:

$$C(l) = c_0 + c_1^{-bl}, \tag{1}$$

where c_0 – fixed component of the cost; c_1 – the basis of power function; b – some rate. Growing crop production in these areas (A_1, A_2 or A_3)(eg. dills, lettuce or cabbage), harvest will be gathered from one unit of area and its value will be $C(A_1)$, $C(A_2)$ or $C(A_3)$ without tranportation costs. This value depends on the production quality, however, it will not be the subject of further research. Therefore, not evaluating the transportion costs, it would be purposeful to grow this production not nearer than at the distance of l_1, l_2 or l_3 (respectively) from a city (consumer). The further phytotron will be mounted from the city, the greater differences will be:

$$C_{A1}(l) = C(A_1) - C(l), \tag{2}$$

$$C_{A2}(l) = C(A_2) - C(l), \tag{3}$$

$$C_{A3}(l) = C(A_3) - C(l). \tag{4}$$

$C_{A1}(l)$, $C_{A2}(l)$ and $C_{A3}(l)$ dependences are presented in the second, third and fourth graphs (Fig. 2) where C is an economic rate. The costs ($\{C_{Ti}(A_1, N_i, l)\}$), transporting the amounts N_i of production A_1 of one unit of area to a consumer, and ignoring some inessential components, will directly depend on the distance l. In the case of three quality classes they will be the following: $C_{T1}(A_1, N_1, l)$, $C_{T2}(A_1, N_2, l)$ and $C_{T3}(A_1, N_3, l)$. The differences will constitute producer's profits:

$$C_{p1}(l) = C_{A1}(l) - C_{T1}(A_1, N_1, l), \quad (5)$$

$$C_{p2}(l) = C_{A1}(l) - C_{T2}(A_1, N_2, l), \quad (6)$$

$$C_{p3}(l) = C_{A1}(l) - C_{T3}(A_1, N_3, l). \quad (7)$$

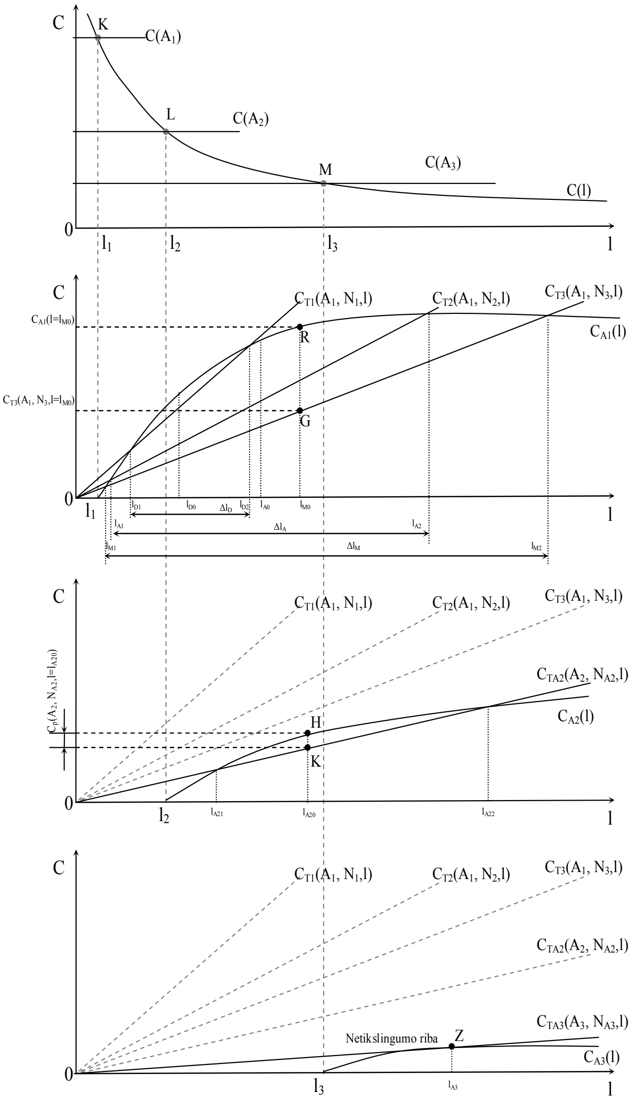

Fig. 2. The choice of the arrangement variants of management means

Therefore, it will be purposeful to mount phytotrons for the manufacture of the production of the highest quality class, at the distance of l_{D1} to l_{D2}, of medium class at the distance of $l_{A1} \div l_{A2}$ and of the lowest class at the distance of $l_{M1} \div l_{M2}$ (see Fig. 2, the second graph). Having the distance l_{M0} which is a maximum difference,

$$C_{A1}(l) - C_{T3}(A_1, N_3, l) = C_{A1}(l = l_{M0}) - C_{T3}(A_1, N_3, l = l_{M0}), \quad (8)$$

the most rational decision would be to mount the phytotrons ensuring such quality and amounts of manufacture at the distance of l_{M0} from a city. The best place to grow crop production of higher quality is the distance l_{A0} from a city, while the distance l_{D0} is the best for growing the production of the highest quality. Both places are at the intervals of Δl_A and Δl_D but not in their centres. The phytotrons mounted at the distance l_{A20} from a city would be most suitable for the production A_2 (see Fig. 2, the third graph). However, the transportation costs $C_{T1}(A_1,N_1,l)$, $C_{T2}(A,N_2,l)$ and $C_{T3}(A,N_3,l)$ would make such manufacture unreasonable. Even reducing the transportation costs of production A_2 from one unit of area quite much (up to $C_{TA2}(A_2, N_{A2}, l)$), the profit would be much lower (than in the case of A_1), although it would be the maximum profit $C_p(A_2, N_{A2}, l=l_{A20})$ in these conditions. This is determined by the nature of C(l) change.

The function $C_{TA3}(A_3, N_{A3}, l)$ shows the limit of inexpediency of the manufacture of the production A_3 (due to high transportation costs) (see Fig. 2, the fourth graph).

Due to the high cost of land at the interval Δl_D, the means of manufacture which are intended for the manufacture of small amounts of the highest quality production need to be concentrated at the maximum. Here the issues of pollution reduction, waste utilization and other problems arise. Mounting phytotrons at the interval Δl_A, the requirements for their techical parameters are slightly smaller. However, the production produced in the first zone is meant for gourmets, patients, children and so on, in the second zone it is meant for demanding consumers, whereas in the third zone it is meant for mass consumers who buy large amounts of it in the shops, markets and so on.

The choice of the types of phytotrons

At present plants are mostly grown directly in the ground, water medium, air medium which is periodically irrigable and artificial vapour. The technologies of the second, third, fourth types are called hydroponics, aeroponics, diaponics and the phytotrons meant for this are called hydropones, aeropones and diapones. Technical peculiarities of this equipment (the phytotron management systems) are presented in Table 1.

Table 1. Peculiarities of phytotron management systems

No.	The type of phytotron	Way of mounting phytotron	Peculiarities of phytotron management systems
1.	Diapone	D (see Fig.3, 4 and 5)	The integrated and concentrated electronic management system; a small number of sensors and performance devices; exceptional flexibility and adaptation of management systems; not more than two management levels; high automation level; the management of temperature, illumination and vapour (together with supply); relatively small overall dimensions; minimal human-operator's activity.
2.	Aeropone	A (see Fig. 6)	Dispersed and integrated electronic management system; many sensors and performance devices; four and more management levels; the electronic research system of the conditions of the plants; big

No.	The type of phytotron	Way of mounting phytotron	Peculiarities of phytotron management systems
			enough flexibility of management technologies; the management of sensors, performance devices, their groups, the parameters of the environment and integrated management of phytotrons; relatively large territories served; constant interaction between ES and a human.
3.	Megapone	M (see Fig. 7)	Combinations of hydropones, aeropones and diapones; the networks of electronic management system of many dispersed types; the electronic research system of the conditions of the plants; universal protection systems against various contingency; the management systems of development; constant analysis and management of complex efficiency [2].

The scheme of diapone section is presented in Fig. 3. Separate management components of illumination, artificial vapour and temperature and the components of the board identification are mounted in each isolated section of diapone. These components are connected to a computer which contains the programs, implementing the sprouting, nurturing and protection technologies of variuos plants $\{A_i\}$. Having inserted the board with the seeds of any plant (eg. A_i) which lets the roots through, and which having closed this section, the computer identifies the future plant (this is done any time when the doors are opened and closed) and activates the programs, coherently implementing sprouting, nurturing, protection and other technologies. When vegetation cycle ends, the computer informs an operator about it.

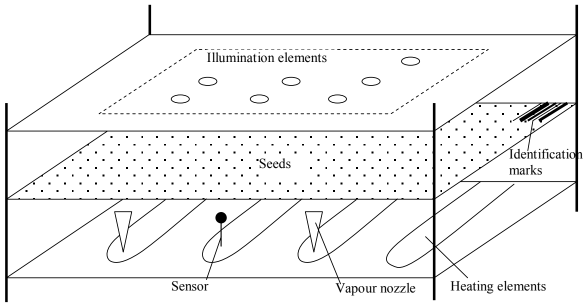

Fig. 3. The scheme of diapon section

The structure of the management systems of diapone is presented in Fig. 4. (ES – electronic system).

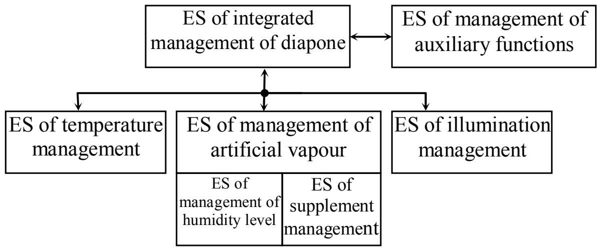

Fig. 4. The structure of the management systems of diapone

The examples of bigger diapone arrangement are presented in Fig. 5.

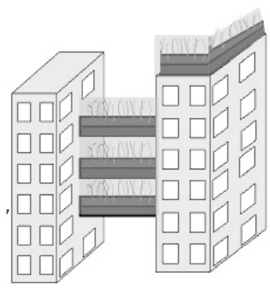

Fig. 5. The examples of the diapone arrangement

ES structures of aeropone and megapone management are presented in Fig. 6 and Fig. 7.

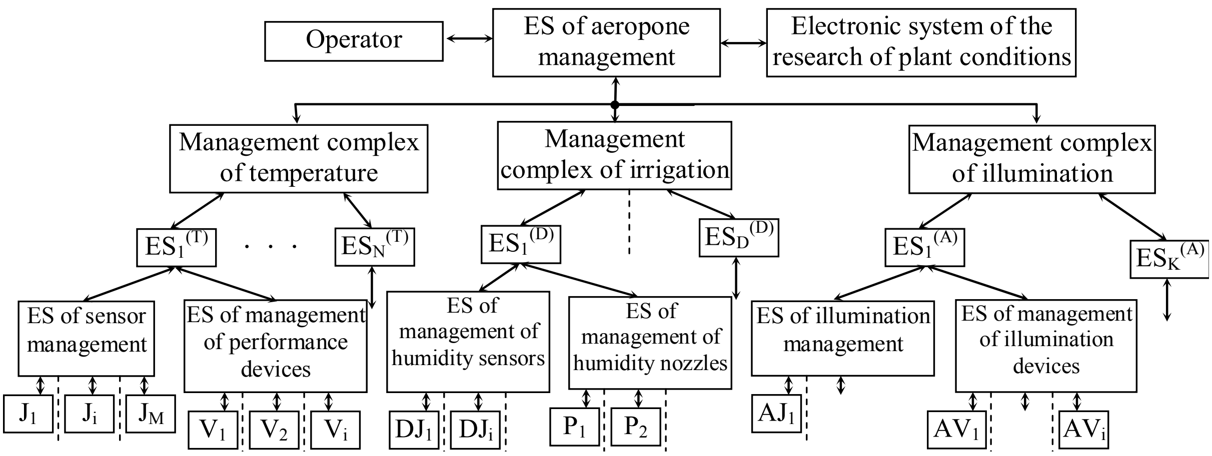

Fig. 6. ES of aeropone management ($E_i^{(T)}, ES_i^{(D)} and ES_i^{(A)}$, – ES of management of i–th temperature, humidity and illumination components; J_i, V_i – temperature sensors and performance devices; DJ_1 ir P_1 – humidity sensor and nozzle)

Here only the analysis principle of phytotron arrangement and management peculiarities is presented. While improving this research, it should be considered that the quality of a product in any phytotron is partly random. The values N_1, N_2, N_3 and $\{C_{Ti} (A_1, N_i, l)\}$are random as well. Therefore, the statistical models would be more suitable for solving these tasks [4,5].

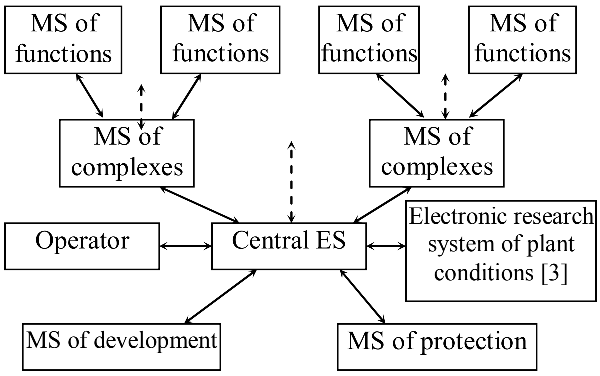

Fig. 7. ES of megapone management (MS – management system)

The modeling of phytotron arrangement in a region

In the first graph of Fig. 2 only three functions are shown: $C(A_1)$, $C(A_2)$ and $C(A_3)$. In general, this is the set of functions $\{C(A_i)\}$. Any $C(A_i)$ depends on the type of phytotron, the conditions of the environment or even the distance l. The functions$\{C_{Ai}(l)\}$, $\{N_j(A_i, t)\}$ and $\{C_{Tj}(A_i, N_j, l, t)\}$ are also partly random (Fig. 8). Thus, implementing the algorithm of choice of phytotron arrangement in a region, it is necessary to use the statistical models of these functions.

The values of the production of type A_i from one area unit of diapones, aeropones or hydropones: $C_D(A_i, t)$, $C_A(A_i, t)$ and $C_N(A_i, t)$ are partly random and their mean values vary in time (Fig. 9).

Even at the initial point (t=0), the rate values $C(A_i)$(Fig. 2) of any type of phytotron (eg. hydrotron) are random (see Fig. 9). Their initial distribution density $f_H(C_H(A_i, t=0)$ and mean value $C_{HV}(C_H(A_i, t=0)$ vary up to $f_H(C_H(A_i, t'))$ and $C_{HV}(A_i, t')$ after time t‘. Therefore, using the chosen value $C_{Hp}(A_i, t')$ with probability in the model,

$$P_H(A_i,t')=\int_{C_{Hp}(A_i,t')}^{\infty} f_H(C_H(A_1,t'))dC_H(A_1,t'), \qquad (9)$$

we will be able to ensure that this value will not be smaller than the chosen one. This will also determine the contingency of $C_{Ai}(l)$. Random natures $\{N_j(A_i, t)\}$ and $\{C_{Tj}(A_i, N_j, l, t)\}$ determine the contingency of $C_{pi}(l)$ (see formulas (5) – (7)). Thus, the existing situation can be presented by the graphs in Fig. 10.

As $C_{Ai}^{(H)}(l,t)$ (in the case of hydropones) and $C_{Tj}(A_i, N_j, l,t)$, their mean values ($C_{Aiv}^{(H)}(.)$ and $C_{Tjv}^{(H)}(..)$) and distribution natures (eg. from initial – $f_1(C_{Ai}^{(H)}(l_1,t))$) vary, when hydropone is at the distance of l_{HO} from a consumer, $C_{Aip}^{(H)}(l_{H0},t)$ chosen for calculations and (mean) value $C_{Tjv}(A_i, N_j, l_{H0}, t)$, the profit earned from a unit of area

$$C_p^{(H)}(A_i,N_j,l_{H0},t)=C_{Aip}^{(H)}(l_{H0},t)-C_{Tjv}(A_i,N_j,l_{H0},t), \qquad (10)$$

will be ensured with probability

$$P_p^{(H)}(A_i,N_j,l_{H0},t)=0{,}5\int_{C_{Aip}^{H}(l_{H0},t)}^{\infty} f_2(C_{Ai}^{(H)}(l_{H0},t))dC_{Ai}^{(H)}(l_{H0},t). \qquad (11)$$

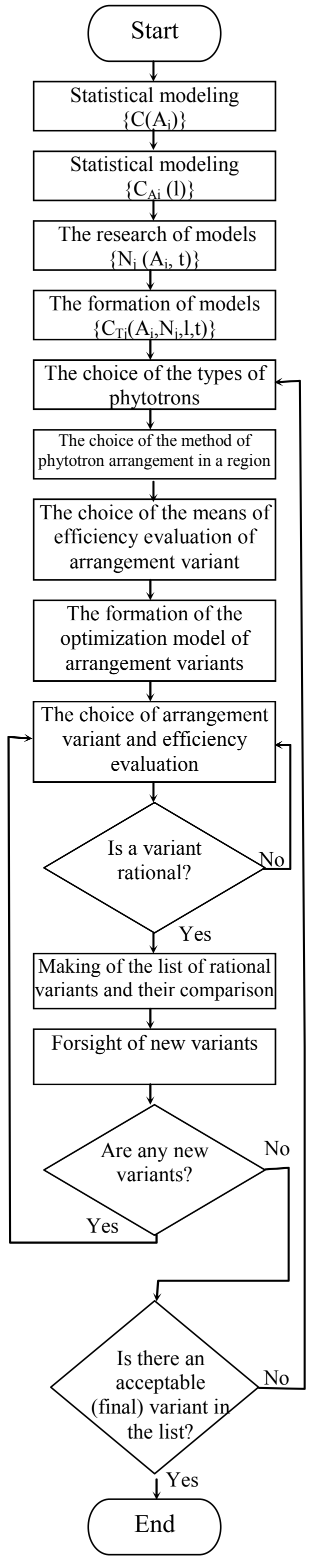

Fig. 8. The algorithm of choice of phytotron arrangement in a region

Changing the chosen values $C_{Aip}^{(H)}(\cdot)$ and $C_{Tjp}(\cdot\cdot)$, it is possible to calculate the future profit which can be ensured with desirable probability.

The methods of the choice of phytotron types and arrangement in a region (see Fig. 8) are interrelated. The solution principles of these tasks are illustrated by Fig. 11.

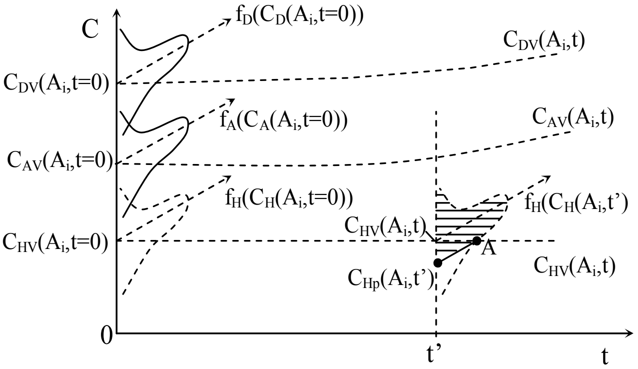

Fig. 9. Value distributions and variation

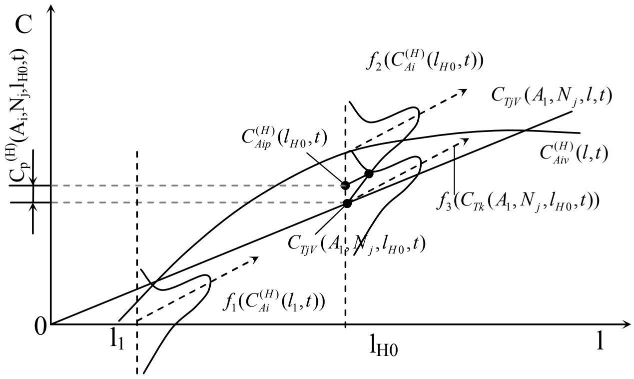

Fig. 10. The finding of the value $C_p^{(H)}(A_i,N_j,l_{H0},t)$

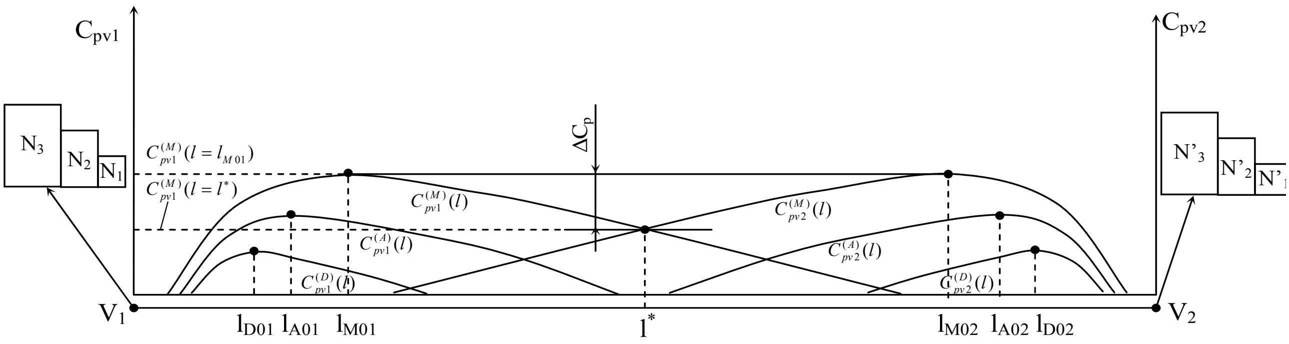

Fig. 11. Phytotron efficiency between two consumers (V_1 and V_2)

It can be observed from the analysis presented above that the needs of both consumers of the production A_i (see Fig. 1) and all profit functions are random values. Therefore, any function (eg. $C_{pvi}^{(M)}(l)$) in any place (eg. l_{M01}) at any time can be described by the distribution density of values $fx(C_{pvi}^{(M)}(V_1,l_{M01},t)$. However, statistical model of phytotron arrangement in a region is very complicated, thus let us analyze the principles of the choice of phytotron types and their arrangement in the case of the determined values. If the highest quality of the production A_i was ensured by diapones, medium by aeropones and the lowest by megapones, then we could tell from Fig. 11 that diapones and aeropones would be mounted separately next to every consumer (eg. a city) at the distances of l_{D01}, l_{A01}, l_{D02} and l_{A02}. It is not still clear where megapones should be mounted. The most suitable area for this would probably be from l_{M01} to l_{M02}. The concrete place will be determined by both consumers' demands for this production (N_3 and N_3'). When $C_{V1}(l)$ (see Fig. 2, in the first graph C(l)) is equal to $C_{V2}(l)$, and $N_3=N_3$', then megapones could be mounted at the distance of l^*. It is possible to decide after the analysis of the economic rates of these variants whether to mount one megapone of double capacity in the place l^* or to build two smaller ones in the places l_{M01} and l_{M02}. If

$$C_{pv1}^{(M)}(A_i,l=l_{M01})=C_{pv2}^{(M)}(A_i,l=l_{M02}), \qquad (12)$$

or

$$\Delta C_p(A_i)=C_{pv1}^{(M)}(A_i,l=l_{M02})-C_{pv1}^{(M)}(A_i,l=l^*), \qquad (13)$$

then to mount one megapone of double capacity ($2N_3$) at the distance l^* from both consumers will be purposeful when this condition is fulfilled:

$$\Delta C_p(A_i)\le C^{(M)}(A_i,N_3)-C^{(M)}(A_i,2N_3), \qquad (14)$$

where $C^{(M)}(A_i,N_3)$ and $C^{(M)}(A_i,2N_3)$ (see Fig. 2, $C(A_1)$) – the values of the production A_i gathered from the megapone of capacity N_3 and $2N_3$ (respectively) of one unit of area. When $N_3\neq N_3$' but the condition (14) is valid, then the optimal distance between the united megapone (providing both consumers with the production A_i) and the consumer V_1 is calculated, using this operator:

$$\max_l[N_3C_{pv1}^{(M)}(A_i,l)+N_3{}'C_{pv2}^{(M)}(A_i,2l^*-l)],l=\overline{0,...2l^*}. \qquad (15)$$

To sum up this solution for the set of products $\{A_i\}$, we can choose this operator:

$$\max_l[\sum_{i=1}^{W}N_{3i}C_{pv1}^{(M)}(A_i,l)+N_{3i}{}'C_{pv2}^{(M)}(A_i,2l^*-l)],l=\overline{0,...2l^*}, \qquad (16)$$

where W – the number of product types; N_{3i} and N_{3i}' – the demands of consumers V_1 and V_2 for i-th type of products.

If one aeropone or megapone is mounted for several consumers, then one of these optimization operators is used:

$$\max_{\{l_j\}} . \sum_{j=1}^{V_0} \sum_{i=1}^{W} N_{2ij} C_{pvj}^{(A)} (A_i, l_j), \qquad (17)$$

or

$$\max_{\{l_j\}} . \sum_{j=1}^{V_0} \sum_{i=1}^{W} N_{3ij} C_{pvj}^{(M)} (A_i, l_j), \qquad (18)$$

where l_j – the distance between an equipment and the j-th consumer, V_0 – the number of consumers; $C_{pvj}^{(A)}(A_i, l_j)$ and $C_{pvj}^{(M)}(A_i, l_j)$ – profit which is earned providing the production A_i to the j-th consumer from one unit of area of aeropone and megapone (respectively) when the distance to it is l_j; N_{2ij} and N_{3ij} – the j-th consumer's demand of the second and third levels of quality of the i–th type production.

It is possible analogically to choose a rational variant of several the same phytotrons or several types of phytotron arrangement in a region.

Conclusions

The peculiarities of electronic management systems of phytotrons depend on the requirements for the quality of the products raised there and also on the distance between it and a consumer.

Using economic criteria of the arrangement of various types of phytotrons in territories, rational distances among diapones, aeropones and/or diapones and consumers and the quantities of the products produced can be calculated and at the same time the structures of electronic management systems can be chosen.

Random nature of most factors, operating on phytotrons, determines the necessity of using statistical methods and probabilistic evaluation of the efficiency of management systems.

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Referring to the various purposes of phytotrons and the requirements for their management, three variants of electronis mangement systems are distinguished. It is shown that the phytotrons with the integrated and concentrated electronic management systems are most suitable for the growing of small quantities of high quality crop production. Growing larger quantities of plants, dispersed and integrated electronic management systems are used. The networks of electronic management systems would be most suitable for managing very big phytotrons. The summarized structures of these systems are presented. The algorithm of the choice of phytotron arrangement in a region is presented. The expediency of statistical modeling for choosing rational phytotron arrangement is justified. Ill. 11, bibl. 5 (in English; summaries in English, Russian and Lithuanian).

П. Балайшис, Д. Эйдукас, Е. Керас, Л. Гочелкиене. Анализ вариантов размещения фитотронов и управления ими // Электроника и электротехника. – Каунас: Технология, 2009. – № 4(92). – С. 93–98.

На основании анализа различного назначения фитотронов, требований к их управлению выделены три варианты электронных систем управления. Показано, что для выращивания небольших количеств продуктов высокого качества лучше всего подходят фитотроны с интегрированными, сосредоточенными электронными системами управления. При выращивании значительно больших объемов продуктов лучше применять рассредоточенные, интегрированные электронные системы управления. Для управления в очень больших фитотронах лучше всего подходят сети электронных систем управления. Приведены обобщенные структуры указанных систем. Приведен компьютерный алгорифм рационального размещения фитотронов в регионе. Обоснована целесообразность применения для выбора рационального варианта размещения фиторонов методов статистического моделирования. Ил. 11, библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

P. Balaišis, D. Eidukas, E. Keras, L. Gočelkienė. Fitotrono išdėstymo ir valdymo variantų analizė // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 4(92). – P. 93–98.

Atsižvelgiant į įvairių fitotronų paskirtį, reikalavimus jų valdymui, skiriami trys elektroninių valdymo sistemų variantai. Parodyta, kad mažų kiekių aukštos kokybės augalinei produkcijai auginti labiausiai tinka fitotronai su integruotomis sutelktomis elektroninėmis valdymo sistemomis. Auginant didesnius augalų kiekius, naudotinos išskirstytos, integruotos elektroninės valdymo sistemos. Labai dideliems fitotronams valdyti geriausiai tiktų elektroninių valdymo sistemų tinklai. Pateiktos apibendrintos šių sistemų struktūros.

Pateiktas fitotronų išdėstymo regione parinkimo algoritmas. Pagrindžiamas statistinio modeliavimo, parenkant racionalų fitotronų išdėstymą, tikslingumas. Il. 11, bibl. 5 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).