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OPTIMIZATION MODEL OF VEGETABLE PRODUCTION STRUCTURE IN SERBIA

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ABSTRACT

Indoor vegetable production, or production in greenhouses enables year-round production, the combined off-season production, greater control of diseases and pests, but also significantly greater production value compared to open field crop production. The aim of this paper is to determine such a structure of vegetable production in greenhouses that will realize the maximum financial result considering various biotechnological, production, technological and market constraints. In this context, model for optimization of vegetable production structure in greenhouses was formulated, and at the same time, model analysis and model solving was made using the method of linear programming and the software package "LINDO". Model was analyzed in three variants, depending on the selected optimality criterion: maximization of net income (variant I), maximization of economics of production (variant II), minimum deviation from the extreme values (variant III). The results show the optimal sowing - planting structure for all three variants of defined model; the participation of certain groups of crops in the overall sowing - planting structure; the required number of working hours in the observed months of working peaks; that variant I achieves the highest net income for defined limiting conditions (4.216.867 din); that variant II achieves the highest economics of production (2,25), while variant I and variant III generate the same economics of production (2,20).Moreover, variant I realized the greatest value ofproduction (7.080.300 din), but also the highest variable (2.863.433 din) and total costs (3.263.433 din). Published data of various experimental paperworks were used for this analysis, as well as data from the accounting records of the farms and data of Statistical Office of the Republic of Serbia.

Keywords: *vegetable production, optimization, model, greenhouse.*

INTRODUCTION

Vegetable production has great economic importance for agricultural development, but also for the overall economic development of the Republic of Serbia. Different methods and production systems, such as indoor vegetable production, enables year-round production, the combined off-season production, greater control of diseases and pests, but also significantly greater production value compared to open field crop production. In this context, model for optimization of vegetable production structure in greenhouses was formulated, and at the same time, model analysis and model solving was made using the method of linear programming and the software package "LINDO", which proved to be very successful instrument for optimizing the vegetable production structure in greenhouses.

Given the importance of vegetable production, a great number of authors dealt with the problem of determining the optimal structure of vegetable production.Nikolić (2014) in the master's thesis analyzed the vegetable production on family farms in Vojvodina, in order to define the optimal structure of vegetable production that will give the best economic effects, that will meet the market needs and that will enable the intensive land use. Krasnić (2004) tested models for optimizing the production structure for industrial processing and for consumption of fresh vegetables, in order to determine the optimal structure of vegetable production using the method of linear programming. Novković et al. (2011) have paid special attention to the optimal structure of vegetable production on family farms. They defined the general model oflinear programming for optimizing the sowing structure of vegetables, in order to meet internal and external conditions of production and trade, to ensure maximum use of capacity and to be economically most efficient.

Stamenkovska et al. (2013) applied the model for optimizing the vegetables production on the hypothetical farm - family farm in the Republic of Macedonia, in order to improve decision making process on family farms in Macedonia. For this purpose, a general linear programming model was used which is quite flexible, thus offers the possibility of adding more companies engaged in this type of production.

Radojevic (2003) presented a model of linear programming for optimal planning of vegetables structure production, intended for industrial processing, in order to point out the possibility of rational land use and achieve better economic effects.

The aim of this paper is to determine such a structure of vegetable production in greenhouses that will realize the maximum financial result considering various biotechnological, production, technological and market constraints.

MATERIALS AND METHODS

The paper presents an analysis of the defined model in three variants, depending on the selected optimality criterion: maximizing net income (variant I), maximizing economics of production (variant II), minimum deviation from the extreme values (variant III). Considering the defined optimality criterion, in addition to the classical method of linear programming, optimization of vegetable production based on multiple criteria of optimality will be applied, which will, among other things, resolve the issue of the optimal production structure based on maximum efficiency, i.e.,economics of production. Multi-criteria optimization indicates that the optimum of a phenomenon or a process is determined based on several criteria, whereby the mutual independence of the set criteria is assumed. That means that the obtained optimal solutions will differ from each other, and therefore it is necessary to establish the compromise solution which would mostly satisfy specific criteria. Therefore, the specificity of this model compared to the classic model of linear programming is the complexity of limiting conditions matrix and the existence of multiple optimality functions. For optimization the vegetable production structure based on maximum effectiveness, the classic linear programming model is applied, while maximizing the production efficiency (due to nonlinearities of relation), fractional linear programming is applied. Since the two optimality criterion is defined, it is necessary to find a solution that will satisfy both of functions criteria. Such a solution is a compromise solution and represents determination of the production structure satisfying each of the defined optimality criteria (Novković, 1989). Since the two main economic criteria are defined, a compromise solution is determined by a combination thereof, based on the maximum effectiveness and maximum production efficiency. If we take into account these criteria, then a compromise model between maximizing the effectiveness and efficiency, based on minimum differencesis as follows:

$$min\ d_1 + d_2$$
$$npy + d_1 - \gamma\ Np_{max} = 0$$
$$vpy + d_2 = Ep_{max}$$
$$vty + \gamma Ft = 1$$
$$Ay_i - \gamma b \ \langle\!\!-\!\!\rangle\ 0$$
$$x_i = \frac{y_i}{¥}$$

d1 = maximum effectiveness deviation
d2 = maximum efficiency deviation
np = planned net income per unit of independent variable
Np max = maximal net income
vp = planned production value per unit of independent variable
vt = variable costs per unit of independent variable
Ft = total fixed costs
Ep max = maximal production efficiency
A = matrix of technical coefficients
b = vector constraints
γ = additional variable
yi = independent variable in the model
xi = the actual value of independent variable.

Activities in defined model are independent variables, and refer to different types of vegetables. At the same time, vegetable types from the model can be repeated several times, as a result of crop rotation, previous crop types, and the seeding order. Constraints relate to limiting conditions of land area, workforce, and of course, the time of sowing - planting. Considering that the study relates to family farms, the optimality function criteria includes gross margin, representing the difference between the production value and variable costs. Using these categories as determinants to maximize optimality functioncriteria, the negative impact on the allocation of fixed costs is eliminated, which can cause some incorrect solutions

(Novković et al., 2008). Defining mathematical model indicates converting the actual relations in the observed object of research in the set of logical relations, defined by mathematical symbols (Novković, 1989). In this way, model solving enables the use of certain mathematical methods. Accordingly, for the purposes of this study, six basic groups of vegetable crops were defined, and list of all the independent variables, as well as their respective symbols are shown in Table 1.

Table 1. Symbols and names of independent variables in optimization model of vegetable production structure in greenhouses

Symbols	Crops	Preceding crop	Group of crops
	i	j	X
X101	Early carrots	/	Root vegetables X1 (101-106)
X102	Beetroot	/	
X103	Spring radish	/	
X104	Winter radish	Cucumber	
X105	Autumn radish	Green beans	
X106	Early chard	/	
X201	New onion	/	Bulb vegetables X2 (201-203)
X202	Spring garlic	/	
X203	Leek	Early potato	
X301	Early potato	/	Tubers vegetables X3 (301)
X401	Tomato (seed)	Spring lettuce	Fruit-bearing vegetables X4 (401-405)
X402	Tomato (seedlings)	Spring spinach	
X403	Pepper(seed)	Spring radish	
X404	Pepper(seedlings)	New onion	
X405	Cucumber	Lettuce	
X501	Peas	/	Leguminous vegetables X5 (501-502)
X502	Green beans	/	
X601	Cabbage	Spring garlic	Leafy vegetables X6 (601-609)
X602	Cauliflower	Early potato	
X603	Spring spinach	/	
X604	Autumn spinach	Tomato	
X605	Winter spinach	Cucumber, Tomato	
X606	Winter spinach	Early carrots	
X607	Spring lettuce	/	
X608	Autumn lettuce	Early carrots	
X609	Winter lettuce	Beetroot, Pepper	

After determining independent variables or activities, the limiting factors in the mathematical model for optimization of vegetable production structure in greenhouses are also defined. The matrix of these constraints includes four groups of limiting conditions characteristic for vegetables production in greenhouses:

1. Constraints on land capacity in the first sowing (1 hectare)
2. Constraints on land capacity in the second sowing
3. Constraints on land capacity in the third seeding
4. Biotechnological limits - minimum / maximum
5. Constraints on direct workforce

In order to solve defined mathematical model, it is necessary to define the optimality function criteria. As already mentioned, as a determinant for optimization the criterion function in this paper, gross margin will be used. As a second criterion for optimization, maximization ofeconomics of productionwill be used, and a compromise solution is determined by combining these two criteria, based on minimum differences.

RESULTS AND DISCUSSION

Table 2 summarizes the optimization results- obtained solutions for all three defined optimality criteria are shown, referring to vegetables production in greenhouses.

Table 2. Optimal vegetables production based on maximizing net income, maximizing economics of production and minimum deviation from the extreme values

Indicators	Variant I	Variant II	Variant III
	Maximization of net income	**Maximization of economics of production**	**Minimum deviation from the extreme values**
NET INCOME (din)	4.216.867	3.256.471	4.156.591
VALUE OF PRODUCTION (din)	7.080.300	5.147.049	6.891.219
VARIABLE COSTS (din)	2.863.433	1.890.578	2.734.628
FIXED COSTS (din)	400.000	400.000	400.000
TOTAL COSTS (din)	3.263.433	2.290.578	3.134.628
ECONOMICS OF PRODUCTION	2,20	2,25	2,20

CONCLUSION

Based on defined mathematical model and defined optimality criteria, and using the software package "LINDO", a solution relating to optimal vegetables production structure in greenhouses was obtained, where all of this leads to the following important conclusions:

• land area of certain types of vegetables that provide optimal sowing - planting structure for all three model variants,

• the share of individual groups of vegetables in the overall sowing - planting structure,

• optimal vegetables production structure in greenhouses according to the time of sowing - planting,

• the required number of employees working hours in the observed months,

• the maximum values of defined optimality function for all three model variants, wherein the variant I achieves the greatest net income, variant II achieves the highest economics of production (2,25), while variant I and III generate the same economics of production (2,20),

• variant I realized the greatest value of production (7.080.300 din), but also the highest variable (2.863.433 din) and total costs (3.263.433 din).

• the reliability of obtained optimal solution, which indicates competitiveness between individual production lines, as well as the limits within the coefficients can be changed, whereby the current optimal solution will remain optimal.

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