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DECISION SUPPORT MODEL FOR ENERGY EFFICIENT GREENHOUSE PRODUCTION SYSTEM
MODEL IZBORA ENERGETSKI EFIKASNOG TEHNOLOŠKO-TEHNIČKOG SISTEMA GAJENJA BILJAKA U KONTROLISANIM USLOVIMA

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ABSTRACT

The aim of the research was to make a simple model which can help producers when starting the greenhouse production system. Based on the chosen plant production and available production area, the model suggests which type of greenhouse farmers should, as well as the optimal technical systems and area for further expansion. The control of the model flow was carried out in the MS Excel program. During the testing phase, it was concluded that the MS Excel is not so good in programming so Quick Basic version 4.5 was used and it appeared simpler and easier for programming. The results show that the model is very suitable for producers, to whom adequate solutions of the greenhouse production systems can be suggested, based on its elementary idea in terms of the greenhouse construction type and technical systems with their capacities.

Key words: *greenhouse, plant production, construction, model, algorithm.*

REZIME

U radu je prikazan model izbora optimalnog tehnološko-tehničkog sistema gajenja u kontrolisanim uslovima. Cilj je bio napraviti model, kao pomoć proizvođačima, kojim bi se, na osnovu njihove početne ideje, sugerisali objekti, tehnički sistemi i prateća infrastruktura sa potrebnim parametrima vezanim za kapacitivnost. Na osnovu izabrane gajene kulture i raspoložive površine model, kao izlazne parametre, daje tip konstrukcije i orijentaciju objekta, tehnološki sistem gajenja, tehnološko-tehničke sisteme ventilacije, grejanja, navodnjavanja i njihove potrebne kapacitete, zatim površinu neophodnu za prateće objekte kao površinu predviđenu za buduće proširenje. Provera algoritma modela je, obzirom na široku primenu MS Office Programa, izvedena u MS Excelu. Tokom provere modela, ustanovljeno je da MS Excel nije jednostavan za programiranje određenih koraka i kontinualno vođenje modela. Jedan deo provere rada modela je izveden u Quick Basic programu, verzija 4.5. koji se pokazao kao puno jednostavniji za programiranje i vođenje algoritma. Utvrđeno je da je predloženi model funkcionalan ali su potrebna dalja poboljšanja u smislu uvođenja većeg broja gajenih kultura i stalnog dopunjavanja baze podataka o tipovima i oblicima konstrukcija objekata zaštićenog prostora i pokrivnih materijala.

Ključne reči: *objekti zaštićenog prostora, gajena biljka, konstrukcija, model, algoritam.*

INTRODUCTION

Considering the growth of human population, global climate change and economical crises, there is a need for a constant increase of food production (*Babić and Babić Ljiljana, 2002*). Greenhouse production was introduced during the 1950s as a way of intensifying vegetable production. Since that period researchers have been working on new covering materials, new constructions and new production systems in order to have more energy and ecology efficient plant production. The theories of "high yield" in last century led to intensive energy consumption through the fertilizers, plant protection chemicals and heating energy (*Karadžić, 2005*). In this way, higher yields were obtained but at what price? Energy consumption was much higher while the ecological aspect of the production became an issue due to the intensive use of agro-chemicals. These two led to the economic analysis which is still the main question in the greenhouse production.

In all these innovations and economic questions, ordinary agricultural producers, when trying to start this kind of production, can easily give up the idea without proper guidance. Greenhouse production is a production system that needs a good management. If things are not clear to the producer in the beginning than greenhouse system will not work properly and it would be economically unstable. Nowadays, for starting a greenhouse production in Serbia, a farmer can contact people from the Faculties of Agriculture, but more often they consult the equipment trading companies. This may have good sides as well as bad sides. Before having any consultation, it would be easier for the farmer to have an idea what he wants, what is he capable of and what are his resources. This was the main motivation for the work presented in this paper.

Experiences in the area of software and modeling in greenhouse production are manly based on climate control and automatisation of the technical systems such as irrigation, fertilizing, venting and heating (*Babić et al., 2004; Karadžić, 2005; Karadžić and Babić, 2005*). In the past, some research has been done concerning the modeling of the whole greenhouse production system and processes. It was most important to determine the factors that define one well-balanced greenhouse production system. The factors proposed by *Stevens et al.,* (*1994*) are market, motivation, previous experience, location etc. If all these conditions are well-balanced than further steps depend on the chosen fruit/vegetable, available surface, production season, soil quality and parcel orientation. These parameters can give a good orientation to the farmers in sense which technical systems they need to use. *Martinov et al.,* (*2006*) give the flow diagram for the establishing of greenhouse system. In the diagram they included all activities, documents and decisions that are needed for the greenhouse project realization. The structure of the diagram is prepared with the help of national and international standards. *Tanasić (2006)* presented the example of how Microsoft Excel software can be used as a tool for making a model and for its verifications. He concluded that the model can be very simple and very easy for use by those who have a PC computer. An interesting example or, better say questionnaire, was presented by NAAN Corporation (*Naandanjain, 2009*). The questionnaire has two parts and it can be filled on-line. First part is about the geographical and location data, together with climatic data. The second part is about whether are you planning a new greenhouse or you are doing the reparation.

A simple model as decision support model for the greenhouse production system was made that should be able to give a start-up idea to any producer that whishes to start this serious business. For using this model farmer needs a PC computer and Microsoft Excel software installed. In this paper main structure of the model is presented and main decision points analyzed.

MATERIAL AND METHOD

Few main questions were used for the model preparation. The first group of questions was based on the chosen fruit / vegetable production and the production surface which is at disposal. These questions are used in model for formulating the greenhouse type of construction, its dimensions and orientation. The second group of questions was based on production technology, time of harvesting and soil quality. These questions are used in the model to provide the information on the time of planting and the production technology that should be applied. The third group of questions is based on construction, covering material, production technology and gives the information on the technical systems and their capacity. The forth group of questions is based on the production area and gives the information on the additional surface for storages, protective areas, parking areas etc. All these questions served as a formatting tool for the model algorithm. Based on all these input parameters, and obtained output parameters, the model gives a final report with the exact data about the greenhouse type of construction, covering material, orientation, production area, time of planting, production technology, type of ventilation system and its capacity, type of heating system and its capacity, type of irrigation system and its capacity as well as additional operational surface and protective areas. For the easier determination of the greenhouse type and dimensions an additional database in Excel was made which consists of all available types of greenhouse construction available in Serbia region and their available dimensions (Figure 1).

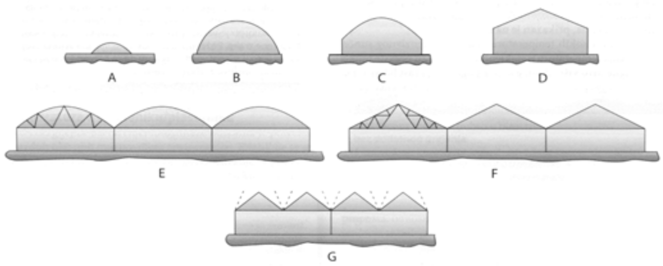

Fig. 1. Type of greenhouse construction included in the model (A – low tunnel, B – high tunnel, C and D – single greenhouses, E, F, G – multi-span greenhouses) (Martinov et al, 2006)

For the orientation and greenhouse type of construction model uses common recommendations given by the international standards (*Nelson, 2003*). For the purpose of production technology determination another database that consists of the planting / harvesting dates for the moment most common vegetables, was made (*Momirović, 2003*). In this part of the model a database of the soil properties that would be optimal for the production (*Momirović, 2003*) was made and inserted to MS Excel 2000. Considering the technical systems, standards of the ventilation rate (*Nelson, 2003; Willits, 1993*) were entered in the model. For the purposes of heating systems calculation, the database of the covering materials, wind speeds and type of the heating systems was made and incorporated in the model (*Nelson, 2003; Martinov et al., 2006*). For easier calculation of the irrigation system capacity, the database of the currently available irrigation systems, suitable for the greenhouse production was made (*Bajkin et al., 2005*). This database includes the type of irrigation system and their technical specifications. Finally, the organizational part of the greenhouse model, standards for the additional surface for storages, working space, parking space and security zones are inserted (*Hanan, 1998; Nelson, 2003*).

RESULTS AND DISCUSSION

Based on the parameters given above, an algorithm was made. One part of it is presented in the Figure 2.

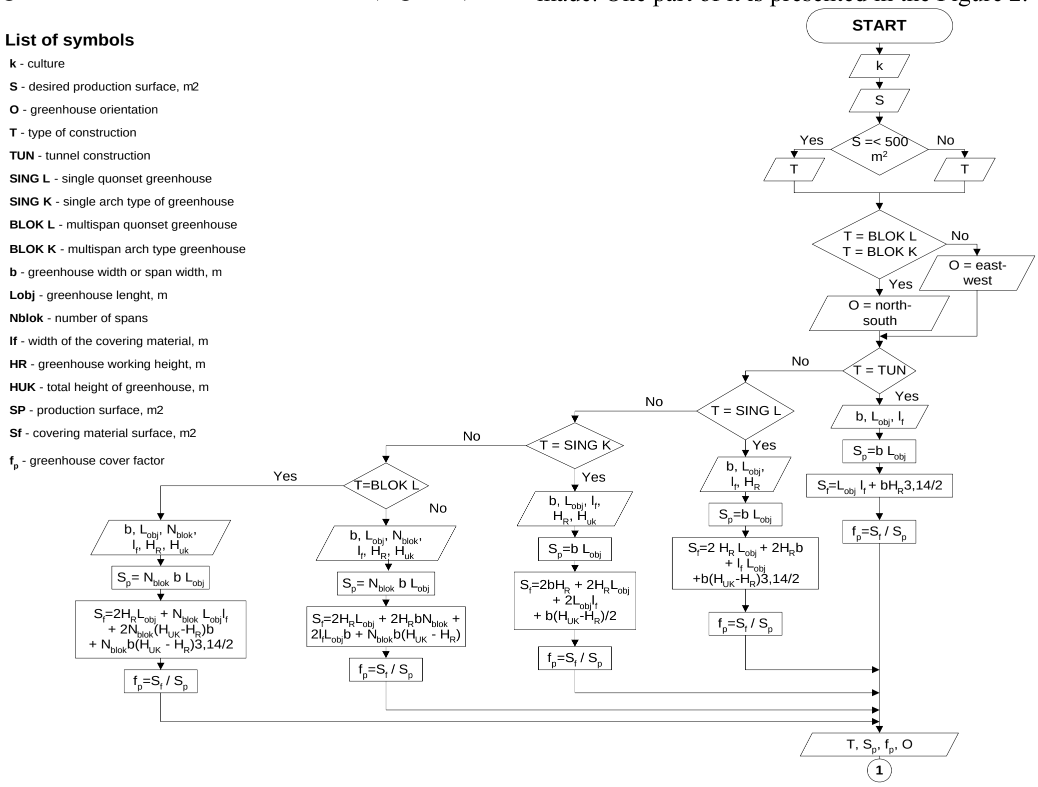

Fig. 2. Part of the algorithm which chooses greenhouse type of construction, dimensions and production surface

This part of the algorithm, based on the inserted culture and the desired production surface suggests the type of greenhouse construction. Model "leads" the user to the database of the types of greenhouse construction where he chooses one type and its dimensions. Based on the parameters that were chosen by the user, the model suggests orientation, calculates production surface and gives the covering material / production surface ratio that is needed for further steps in the model. The next part of the algorithm represents the part of choosing the production season and technology. The user is asked about the time of harvesting and about the basic parameters of the soil quality (organic matter content, levels of nitrogen, phosphorus and potassium and pH level). Analyzing the user's answers, the model suggests the time of planting and the production technology (Figure 3).

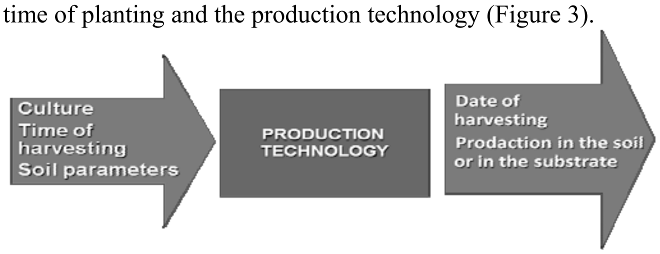

Fig. 3. Input and output parameters for the production technology suggestion

In Figure 4, input and output variables for the optimization of the ventilation system are presented.

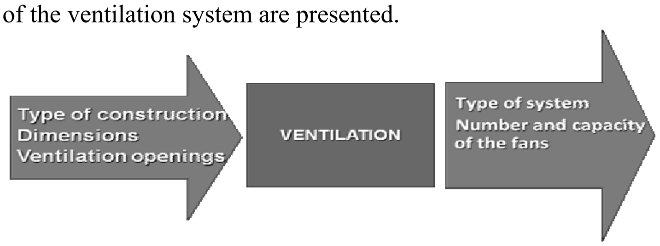

Fig. 4. Input and output variables for the ventilation system suggestion

In this case, the model already has the needed values so this parameter is automatically calculated when construction, dimensions and surface of ventilation openings are known. The final output will be given through the capacity of a single fan (m^3/min) and their total number in the greenhouse. In case of heating, model suggests whether heating is needed or not. The input variables are already known except that the user must suggest what covering material will be used, predict wind speed in the area and determine the desired heating system (air heating, pipe central heating, etc.).

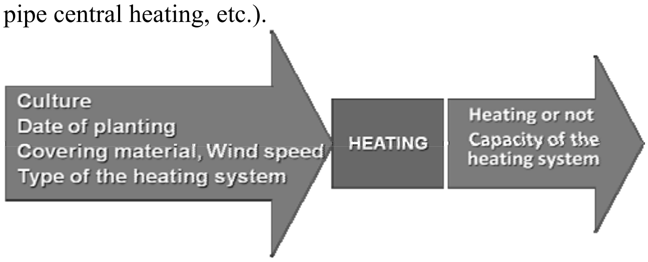

Fig. 5. Input and output variables for the heating system suggestion

Final output will be given through the heat losses of the greenhouse (kW). Regarding the irrigation system, the model already has some values. The user must decide about the type of system (model suggests him concerning the plant production). After choosing the type, the user must decide how many irrigation cycles per day he wants.

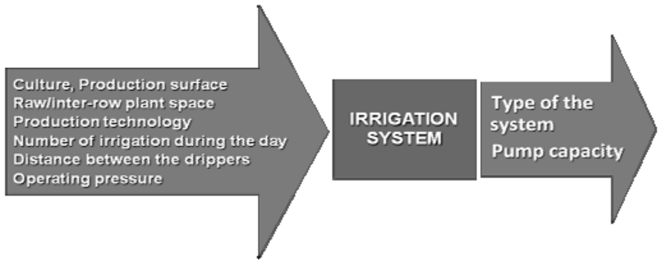

Fig. 6. Input and output variables for the irrigation system suggestion

The output of this step is what type of system did the user choose, what is the capacity of the system and of the pump and how much water per cycle does he need.

Final step in the proposed model is to suggest what is the surface needed for the storages, working offices, protective area etc (Figure 7).

Fig. 7. Input and output variables for the additional working area

In this phase, the user must give the data whether or not there is some working area around the future greenhouse and what the surface. Model compares this value to the standard recommendations about the surface of this area and suggests whether user must prepare totally new area or only to plan some more space. The algorithm was realized with the help of Microsoft Excel 2000 in the case of the lettuce production, tunnel greenhouse, adequate soil quality and 10 m^2 of the additional working (operational) area. Figure 8. presents a Final report.

FINAL REPORT	
Culture	lettuce
Type of greenhouse	Tunnel
Tunnel width, m	10
Tunnel lenght, m	20
Orientation	east-west
Number of plants	700-800
Time of planting (month)	12.
Production technology	In the soil
Ventilation system	Natural ventilation
Capacity, m^3/min	
Fan capacity, m^3/min	
Number of fans in greenhouse	
Heat losess, kW	2541,8237
Type of the heating system	Central heating
Type of irrigation system	Micro-irrigation, irrigation tape
Total amount of water per day, l	1531,914894
Total amount of water per cycle, l	1531,914894
Number of cycles	1
Duration of cycle, h	0,5
Duration of irrigation, h	0,5
Pump, kW	0,113475177
Total area needed for greenhouses, additional and protective area, m^2	671,96
Surface of additional working area, m^2	10
Additional working area needed, m^2	30
Additional working area to be built, m^2	20

Fig. 8. A final report of the model

So far this model is still "under construction". For this purpose, only lettuce and tomato were introduced into the algorithm. So, one of the following improvements of the model will have to be introducing more vegetable and fruit species. Next thing is that there are some new types of greenhouse covering materials, as well as new designs and dimensions. All these must be included in the database. The area about the production technology must be widened by further explanation of the substrate production and soilless cultures. Some changes should be made in the sense of irrigation concerning the number and length of irrigation cycles.

During the algorithm implementation, the MS Excel program was found very difficult for programming. For this reason the model function check was done in Quick Basic 4.5 software. Figure 9 shows the first part of the model where type of construction, orientation, production surface and the covering / surface ratio are chosen and calculated.

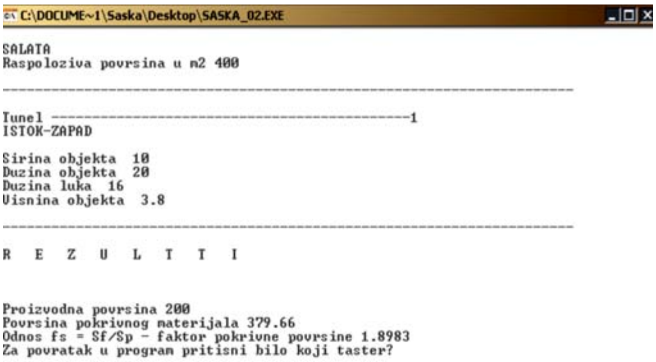

Fig. 9. Output parameters for the first part of algorithm

The same parameters were inserted in the Quck Basic program like in the MS Excel program. Lettuce was chosen for production and available surface was 400 m^2. For the greenhouse construction, the tunnel structure 10 m wide, 20 m in length and 3, 6 m in height. During programming, it was recorded that the data manipulation and usage was far simpler than in MS Excel specially when there was a need for multiple choices.

CONCLUSION

Greenhouse production is a very complex production system that needs to be maintained well and with great attention. The decision about starting this kind of business involves great number variables that need to be analyzed. In this paper, a simple model for farmers is presented. The model is still in the developing stage and a lot of improvements are needed but the possibilities of its use are wide. The aim was to introduce the greenhouse production system to a farmer by letting him know how he can influence the parameters and how changing the one parameter can influence the establishment of the whole system. The proposed algorithm was realized in the MS Excel 2000 Program but during the realization some difficulties occurred that indicate that some other more suitable programs should be used.

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