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Prevention of the development of root on stage of post-harvest storage of sugar beet

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Abstract. This article is devoted to the study of the reasons for the decline in the quality of root crops during post-harvest storage in piles under the influence of harmful microflora. The subject of the research is the process of sugar beet storage in enterprises. The causes of sugar beet mass losses are analyzed. Mathematical models have been developed for the intensity of damage to root crops by the most common types of clamp rot. A description of an automated information system designed to maintain the normative parameters of the microclimate inside the piles by means of information technologies is given.

1 Introduction

The production and processing of agricultural raw materials is one of the most important industrial structures in Russia. In turn, the sugar beet complex is the largest area of the agro-industrial complex (AIC). Its condition largely depends both on the quality of raw materials and on the overall competitiveness of the enterprise that processes it. Therefore, one of the main tasks of the industry is to ensure the maximum production of sugar per seed unit, which is achieved by maintaining the high technological and physical and chemical qualities of beet raw materials [1].

Observations show that in the 2020 season, in a number of areas, the greatest damage to sugar beet was caused by aphanomycetic rot, against which fungicidal seed treatment is not enough, which provides protection only in the early phases of development and does not prevent infection in subsequent periods of root growth. The cultivation of tolerant hybrids can play a significant role in resolving this issue, but they are less productive and, as a rule, are not in demand by agricultural holdings. This serves as a basis for accelerating the search for a balance between productivity and resistance of hybrids.

There is no need to prove that at present, fungicidal treatment remains the most used method for the control of pathogens. But monitoring this problem shows that the spread of sugar beet cercosporosis has recently increased, in relation to which cases of resistance to the applied means of protection have been identified, despite the fact that cercosporosis belongs to a group of diseases with an average risk of developing resistance [2, 3]

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2 Methodology of research

The above arguments of scientists demonstrate that in relation to sugar beet, as for no other crop, all of the above factors are interconnected. In order to solve the problem of root rot, it is necessary to determine what is the root cause. This problem is currently not fully resolved.

The main losses during storage of root crops in clamps are caused by clamp rot caused by the fungus Botrytis cinerea in combination with other microorganisms. This fungus is a typical aerobe, in the affected tissue it develops a multicellular colorless mycelium, and on the surface of rotten root crops it forms a cotton-like, first white, and then gray and finally dark mycelium, which envelops entire groups of root crops, fills the gaps between them, forming a focus of clamp rot.

The most active development of the fungus and the abundant formation of spores by it occurs at a high relative humidity in the pile, close to 100%, and at a temperature of + (25-30) ° C. The germination of conidia of this fungus was observed even at a temperature of +5 °C. However, at a temperature of +(1-3)°C, the development of the pathogen is inactive [2, 3]. The experimental data [4] are shown in Table 1. In addition, to maintain the sugar content of root crops at an optimal level, the humidity during storage of raw materials should not fall below 90-95%.

Table 1. The effect of temperature on the intensity of beet damage by rot pathogens [3, 4].

Air temperature,° C	The root crop destruction intensity on the 10th day, %					
	Ph.betae	A.tenuis	S.sclerotiorum	Fusarium sp.	B.cinerea	P.expansum
3	0	0	0	0	0	0
5	0	0	0	0	1,25	5
10	2,5	1,25	7,5	3,75	2,5	7,5
15	7,5	3,75	10	5	3,75	15
18	10	5	15	7,5	5	15
20	15	7,5	20	8,75	6,25	175
22	12,5	7,5	22,5	10	6,25	175
25	7,5	5	15	11,25	5	20
28	5	2,5	10	10	0	17,5
32	0	0	0	0	0	2.5

On the basis of known experiments (Table 1), we carried out mathematical modeling of damage to root crops by rot pathogens. Got the following models:

1) Growth model *Ph.betae*:

$C_{Pb}=1{,}3339185\cdot10^{27}/(t+a9)^{a2}\cdot\exp(-363{,}22368\cdot10^{28}/(t+a1)^{a4})+a3\cdot t+10\cdot a5\cdot(t+a1)^{a8}+$
$+100\cdot a6/(t+a1)+10\cdot a7.$

2) Growth model *A.tenuis*:

$C_{At}=5{,}7251706\cdot10^{29}/(|t-9{,}95|)^{a2}\cdot\exp(-a3\cdot10^{11}/(t+a1)^{a4})+a5\cdot t+10^4\cdot a6/(t+a1)+$
$+1000\cdot a8/(t+a1)^{1/2}$, at $t\leq 18$°C or $t\geq 25$°C;

$C_{At}=10^4\cdot b1/t^{1/2}+10^4\cdot b2/t+10^3\cdot b3$, at 18°C $\leq t\leq$ 25°C.

3) Growth model *S.sclerotiorum*:

$C_{Ss}=10^4\cdot a1/|t-14{,}457|^{a2}\cdot\exp(-a3\cdot10^9/|t-a9|^{a4})+a5\cdot t+10\cdot a6/|t+a9|+a8\cdot|t-a9|^{1/2}.$

4) Growth model *Fusarium sp.*:

$C_{Fs}=100\cdot a1/t^{a2}\cdot(\exp(-a3\cdot10^{-5}\cdot t^{a4}))^{0{,}67}+10^{-2}\cdot a5\cdot t^{2{,}74}+100\cdot a6+a7/t+a8\cdot t.$

5) Growth model B.cinerea:

$C_{Bc}=607\cdot10^{27}/(t+a9)^{a2}\cdot\exp(-a3\cdot10^{18}/(t+a1)^{a4})+a5\cdot t+10^4\cdot a6/(t+a1)+100\cdot a7+$
$+100\cdot a8/(t+a1)^{0{,}38135}.$

6) Growth model *P.expansum*:

$C_{Pe}=0{,}681738\cdot10^{23}/(t+a1)^{a2}\cdot\exp(-a3\cdot10^3/(t+a1)^{a4})+100\cdot a5\cdot t+10^3\cdot a6/(t+a1)^{1/2}+10^3\cdot a7+$

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at $t \leq 18°C$ or $t \geq 25°C$;
$C_{Pe}=10^6 \cdot b1/t^{1/2}+10^6 \cdot b2/t+10^5 \cdot b3$, at $18°C \leq t \leq 25°C$.

3 Research results

The average relative error in modeling the growth of fungi is 5-6%. Modeling was carried out using an interactive identification system [5-7]. Tables 2 and 3 show the coefficients of the developed mathematical models (1)-(6).

Table 2. The mathematical models (1)-(6) coefficients.

Model's name	*a*1	*a*2	*a*3	*a*4	*a*5	*a*6	*a*7	*a*8	*a*9
Ph.betae	6.1877	17.4007	27.3167	21.7014	-1.022	7.03045	-0.2749	1.22675	11.5373
A.tenuis	11.097	23.2171	0.25416	6.21388	-8.475	0.13802	-4.8817	0.11077	-
S.sclerotiorum	0.6398	2.45173	0.13617	6.08178	-5.449	6.80126	-0.8026	44.2283	0.69649
Fusarium sp.	-1.9729	0.13601	0.21948	3.96945	-0.833	1.43733	80.4011	-0.1433	-
B.cinerea	100.83	16.9978	0.24801	7.78482	-5.58	-6.742	6.7365	-0.4487	0.14337
P.expansum	8.0353	8.50016	0.14574	0.59356	-0.219	0.16783	-0.4916	-	-
Model's name	*b*1	*b*2	*b*3						
A.tenuis	0.3738	-0.8577	-0.3994						
P.expansum	0.2355	-0.5407	-0.2544						

Figures 1 and 2 show the experimental and model temperature dependences of the intensity of damage to the root crop, respectively, by the fungi B.cinerea and P.expansum. The negative lesion intensities obtained at the ends of the graphs in the models are equated to zero.

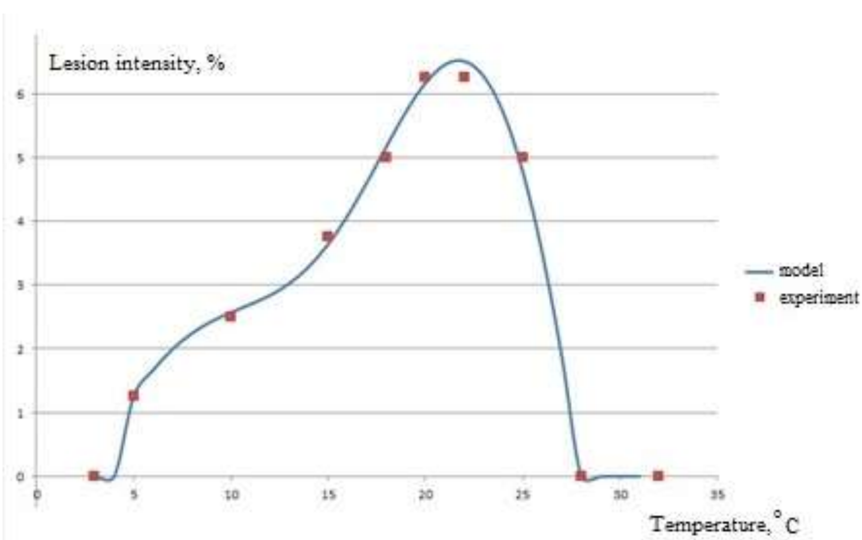

Fig. 1. Intensity of damage to the root crop by the fungus *B.cinerea*.

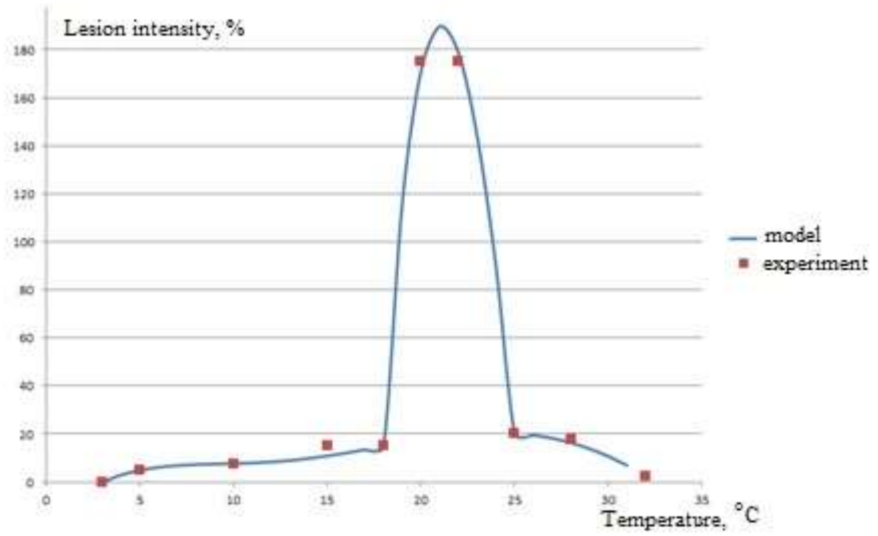

Fig. 2. Intensity of damage to the root crop by the fungus *P.expansum*.

4 Discussion of results

In the emergence and development of clamp rot, regardless of its pathogen, the physiological state of root crops plays an important role. Weakening of the roots can be the result of diseases transferred during the growing season, as well as withering, freezing and mechanical damage. This indicates the need to prevent the influence of low temperatures on root crops in order to maintain the high quality of raw materials [8].

To preserve beets with a high content of sucrose, the following factors must be taken into account: - the state of the seed fund (diseases transferred during the growing season, drying); - growing conditions (weather conditions); - physiological state of harvested root crops (mechanical damage, moisture content of root crops); - conditions for post-harvest storage of beets (temperature, humidity). Within the framework of this work, special attention is paid to the post-harvest storage of beets in piles in order to create and control optimal conditions [8].

The conducted studies revealed the following facts during the storage of beets. Regardless of the change in the temperature of the outside air, the temperature in the heap changes, and most often rises. Moisture and wet spots appear on the surface of root crops. A "fog" is formed. All this leads to the emergence of a lesion, and, as a result, goes into the mass distribution of various fungal pathogens.

It is proposed to automate the process of maintaining the main technological parameters. To create favourable conditions for the storage of root crops, an automated information system (AIS) has been developed and put into operation. The presented AIS is not know-how. This is a way to modernize the ventilation system of piles with the help of information technologies [9, 10]. The technological scheme of the proposed AIS is shown in Figure 3.

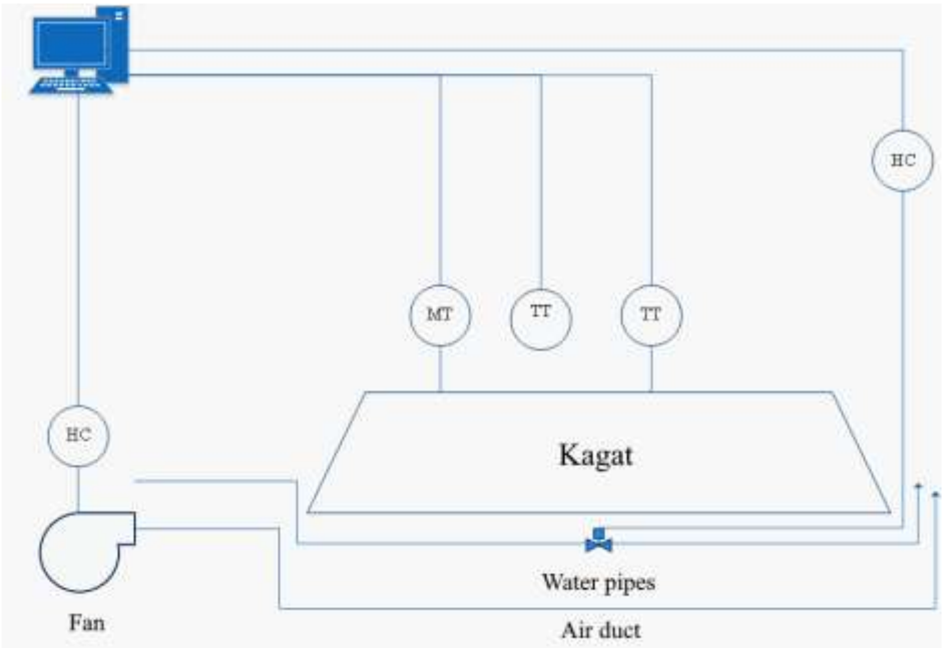

Fig. 3. Technological scheme of AIS.

To obtain information about the climatic conditions of the beet store, it is necessary to install temperature and humidity sensors. Temperature sensors must be provided both inside the pile and in the airspace.

When forming piles, it is necessary to provide ventilation outlets to prevent the formation of moisture in the beet pulp. Air ducts inside the clamps contribute to both forced and natural ventilation of root crops. For forced ventilation, air ducts are connected to fans. With low air humidity in the beet storage, it is necessary to place a water circuit with humidifying spray elements to prevent the drying process.

The information collected from the sensors enters the AIS software module located at the automated workplace of the beet store manager. The core of the module is the control block in which data is collected, processed, and aggregated. In the same block, on the basis of deviations of the values of climatic parameters from favorable, control signals are generated. The signals are sent to the working elements of the actuators, which turn on or off the forced supply of air or water to the corresponding circuits. For the mobility of the AIS, it is proposed to use digital sensors and control devices. The block diagram of the control algorithm is shown in Figure 4.

The operation of the algorithm meets the basic requirements for the functioning of automated systems. When there is a deviation of the temperature inside the pile from the optimal value, the forced ventilation air supply to the ventilation circuit is automatically switched on. A decrease in air humidity inside the pile increases the deviation from the optimal value and the humidifying circuit is automatically turned on. If the humidity rises excessively, the AIS automatically stops the water supply and turns on the ventilation.

The proposed principle of managing beet storage conditions in the post-harvest period contributes to the preservation of the physical and chemical qualities of raw materials and, above all, root sucrose at an optimal level.

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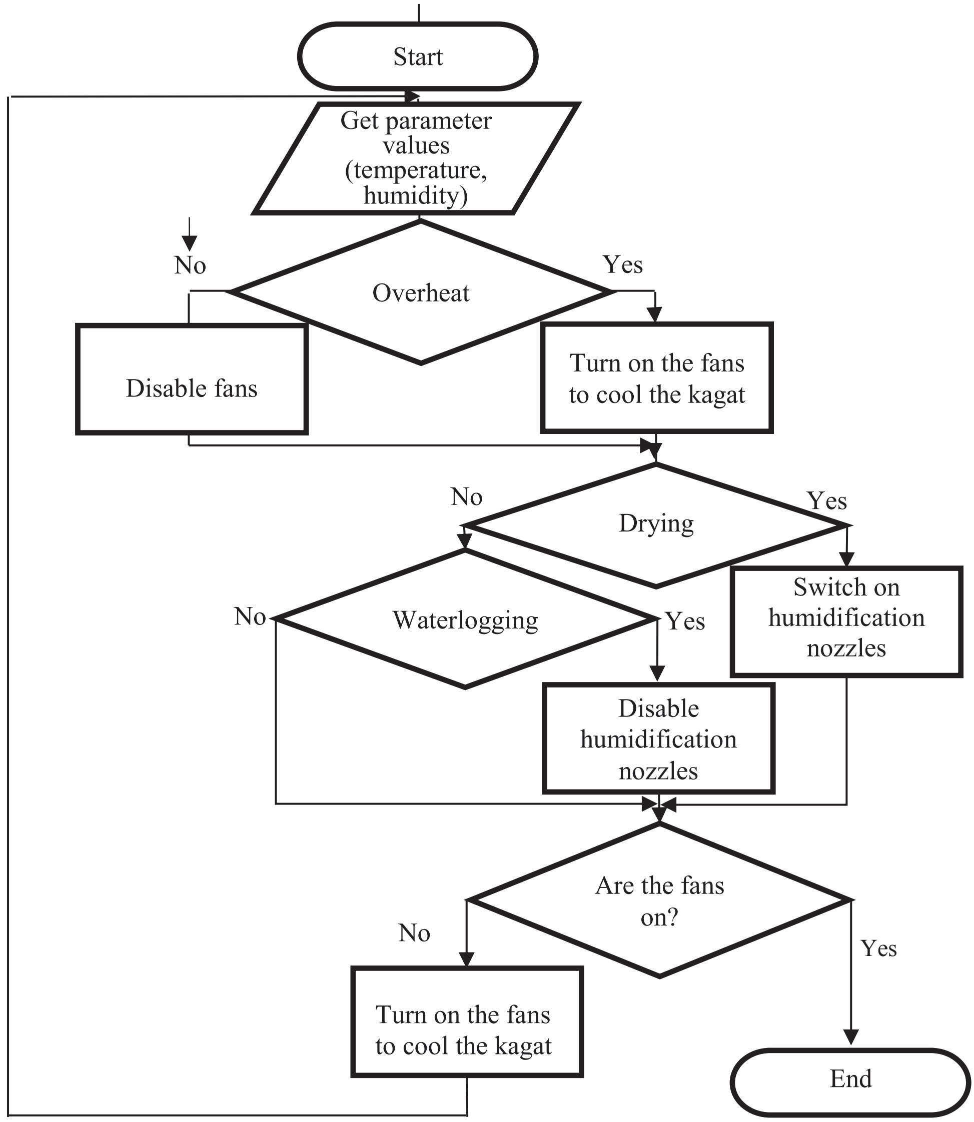

Fig. 4. Regulation of parameters in the beet storage room.

5 Conclusions

Mathematical models of the growth of the most common sugar beet clamp rot fungi have been developed. An interactive identification system was used. The coefficients of the model are obtained and tested. The comparison of simulation results with real data showed that the average relative error lies within 6%. A method is proposed for upgrading the existing parameter control system, designed to maintain favorable conditions inside the beet storage and in the piles themselves. The introduction of AIS will reduce the likelihood of beet mass losses and increase the amount of "healthy" beet mass sent for processing.

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