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METHODICAL PRINCIPLES OF MODELING OF SUBJECT-AGROMETEOROLOGICAL EVENTS IN TECHNOLOGICAL PROCESSES GROWING OF GRAIN CROPS

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Abstract. The article identifies and classifies subject-agrometeorological events in the technological processes of cultivating grain crops. The analysis of these events made it possible to classify them according to the periodicity of their appearance, as well as to indicate the content of the influence of each of them on the course of these processes, which made it possible to develop appropriate algorithms for modeling the time of occurrence of these events.

The distribution of the time of occurrence of subject-agrometeorological events in technological processes of growing of grain crops, in particular: the time of restoration of spring vegetation, the completion of the autumn vegetation period of winter grain crops, the time of reaching their characteristic predecessors, and the patterns of change in the duration of soil warming have been established. The obtained regularities allow to predict (generate) the onset of phases of development of plants and time constraints for the implementation of mechanized operations in the technological processes of cultivating grain crops for different natural and production conditions.

The developed scientific and methodical principles of modeling of subject-agrometeorological events in the technological processes of cultivating grain crops underlie the creation of their computer models. The practical use of these models will allow you to predict the time constraints for performing mechanized operations and the characteristics of the flow of orders for their execution.

The methods of analysis and synthesis, system-factor and system-event approaches to the study of technological processes of cultivating grain crops were used in the work. To develop algorithms for modeling these technological processes, a discrete-event approach was used.

Key words: cultivation, grain crops, subject-agrometeorological events, technological processes, mechanized operations, modeling.

Introduction

The high level of technology of agricultural production, technical complexity and high technology costs require a high level of management of the technical base of agricultural producers, the search for ways to reduce material and energy costs.

Formulation of problem

The search for rational solutions during the acquisition and use of machine-tractor fleet of agricultural producers is one of the most difficult tasks of mechanization of agricultural production. To solve it, it is necessary to consider a large number of factors, some of which are unmanaged and probabilistic. At present, there is no general system approach to the modeling of subject-agrometeorological events in the technological processes of cultivating grain crops, which underlies the creation of simulation models of these processes and prediction of time constraints for the implementation of technological operations in them.

Analysis of recent research results

Many research and methodological works [1 - 19] are devoted to the study of the tendencies of occurrence and influence of subject-agrometeorological events on the flows of requirements for the implementation of mechanized operations in the technological processes of cultivating grain crops. In particular, the causative and consequential connections between events and mechanized operations of partial soil cultivation processes [1, 2], integrated soil cultivation and winter crop sowing [3, 4], protection of plants by spraying [5], collection and after-harvest treatment of crop crops [6-19].

Purpose of research

The purpose of this study is to reveal the methodological principles of modeling the time of occurrence of subject-agrometeorological events in the technological processes of cultivating grain crops, which will enable to increase the efficiency of planning these processes by taking into account the stochastic influence of these events.

Results of research

Analysis of agrotechnological requirements for the cultivation of grain crops made it possible to indicate two main periods of operations and works in the technological processes of cultivating grain crops – spring-summer and summer-autumn [12]. In the spring-summer period technological processes are considered: soil cultivation, sowing of spring crops, care of crops (chemical protection of plants). In the summer-autumn period – harvesting of predecessor, pre-planting of soil, winter wheat seed production.

The peculiarity of the technological processes of cultivating grain crops is that the probabilistic nature of the occurrence of subject-agrometeorological events during their course of time determines the possibility and feasibility of their implementation. Without a thorough analysis of these events it is not possible to ensure the harmonization of technological processes and their effective implementation. Creation and use of computer models of occurrence of subject-agrometeorological events in technological processes will allow to predict the time constraints of the characteristics of flow of orders for their execution.

Subject-agrometeorological events that affect the flow of technological processes of growing crops can be divided into two groups: the first - events that determine the timing of their implementation, the second is the events that cause the suspension and restoration of their execution. Under the influence of these events, funds are formed for the implementation of these processes. The probabilistic nature of the occurrence of agrometeorological events determines the variability in the duration of mechanized operations of the technological processes of growing these crops, both within one year for different regions and within the same region in different years.

The analysis of subject-agrometeorological events in the technological processes of cultivating grain crops (Table 1) shows the following. For the spring-summer period of the implementation of technological processes of cultivating grain crops, there are eight main events, and for the summer-autumn six. Each of the subject-agrometeorological events reflects the action of a limited set of factors that influence the performance of these technological processes. In addition, the content of the effect on the course of technological processes of growing crops of each of the indicated events is different. It should be noted that the frequency of the occurrence of events in these processes, they can be divided into seasonal, which are characterized by a single appearance in a separate season and daily – arise (may arise) every day of the season.

In order to take into account the probabilistic nature of the subject-agrometeorological events of the spring-summer and summer-autumn periods, as well as their influence on the course of technological processes of growing of grain crops, it is expedient to use a statistical simulation modeling of these processes. In particular, in this case, a discrete-event approach to modeling can be used [11].

For this purpose, generalized algorithms for the modeling of subject-agrometeorological events in the process of functioning of arable technological processes in the spring-summer (Figure 1) and summer-autumn (Figure 4) periods have been developed.

Table 1. Analysis of subject-agrometeorological events in the technological processes

№	Period of implementation of mechanized operations of technological processes	Event name	Displays the effect of factors *	Content of influence on the course of technological processes	Classification the periodicity of occurrence in the technological processes
1	2	3	4	5	6
1	Spring-summer period	The onset of physical maturation of the soil	Am, Pp, Tl	Determines the beginning of mechanized soil cultivation operations	Seasonal
2		Heat the soil to the temperature of the sowing	Am, Pp, Tl	Determines the beginning of the implementation of sowing of spring cereal crops	Seasonal
3		The onset of phenological phases of plant development	Am, Pp, Tl	Identify the beginnings of works on chemical protection of plants	Seasonal
4		Precipitation fall	Am, Pp, Tn	Determines the possibility of mechanized operations	Daily

Continuation of Table 1

1	2	3	4	5	6
5	Spring-summer period	The onset and completion of the light period of the day	Am, Tn	Determines the possibility of performing mechanized chemical protection plant operations	Daily
6		Excess air temperature 25ºC	Am, Pp, Tl		Daily
7		The dew disappear	Am, Pp, Tl		Daily
8		Excess wind speed 5 m/s	Am, Pp, Tl		Daily
9	Summer-autumn period	Ripening of the predecessor	Am, Pp	Specifies the start of collecting a predecessor on a given field	Seasonal
10		Completion of harvesting predecessor	Pp, Tn	Determines the possibility of pre-planting soil cultivation	Seasonal
11		Precipitation fall	Am, Pp, Tn	Determine the possibility of performing soil-sowing operations	Daily
12		Completion of pre-planting soil cultivation	Pp, Tn	Determine the possibility of seeding winter crops	Seasonal
13		Completion (predicted) set of cultures of the required amount of active daily average temperatures	Am, Pp, Tl	Determine the time when sowing winter crops needs	Seasonal
14		Completion of time fund tilling winter crops	Am, Pp	Determine the deadlines for the sowing of winter crops, in which the continuation of works is economically inexpedient	Seasonal

* - Am, Pr, Tl, Tn – respectively agrometeorological, subject,, technological and technical groups of factors [13].

In the first stage (Figure 1) the simulation of the time of occurrence of subject-agrometeorological events substantiates the number of implementations of the computer model to ensure its required accuracy and specifies the characteristics of the natural-production conditions (geographical location and characteristics of the production plan) of agricultural producers (AP).

At the second stage (Figure 1), the time of occurrence of physical soil maturity (PMS) (τ_{pms}) is generated. In particular, for the conditions of the L'viv region of Ukraine, the time distribution of the physical soil maturity is consistent with the normal distribution law by an adjusted polynomial, the main statistical characteristics of which are: $\bar{M}[\tau_{pms}]$=85,6 days, $\bar{\sigma}[\tau_{pms}]$=13,4 days [1]. At the third stage (Fig. 1), the time for the restoration of spring vegetation (τ_{rsv}) of winter cereal crops is generated.

Based on the statistical processing of the retrospective data on the time of restoration of spring vegetation (τ_{rsv}) of winter crops in Ukraine, we have established that their distributions are consistent with the normal law and are described by different equations of distribution density (Figure 2). At stage 6 (Figure 1), the duration of the weathered and subtropical intervals of time in the interval from the moment of physical soil maturity to the time of the end of the sowing of heat-loving grain crops is generated.

At the seventh step (Figure 1), the actual timeframe is determined for pre-sowing tillage and sowing of spring cereal crops. For example, the estimation of the mathematical expectation of the time of restoration of spring vegetation of winter grain crops for the conditions of the Lviv region of Ukraine $\bar{M}[\tau_{rsv}] = 90,32\,\text{days}$, and the mean square deviation $\bar{\sigma}[\tau_{rsv}] = 14,23\,\text{days}$

(Fig. 2, a). For the conditions of the Kherson region (Fig. 2, b).
Ukraine: $\bar{M}[\tau_{rsv}]=91,37$ days, $\bar{\sigma}[\tau_{rsv}]=6,99$ days

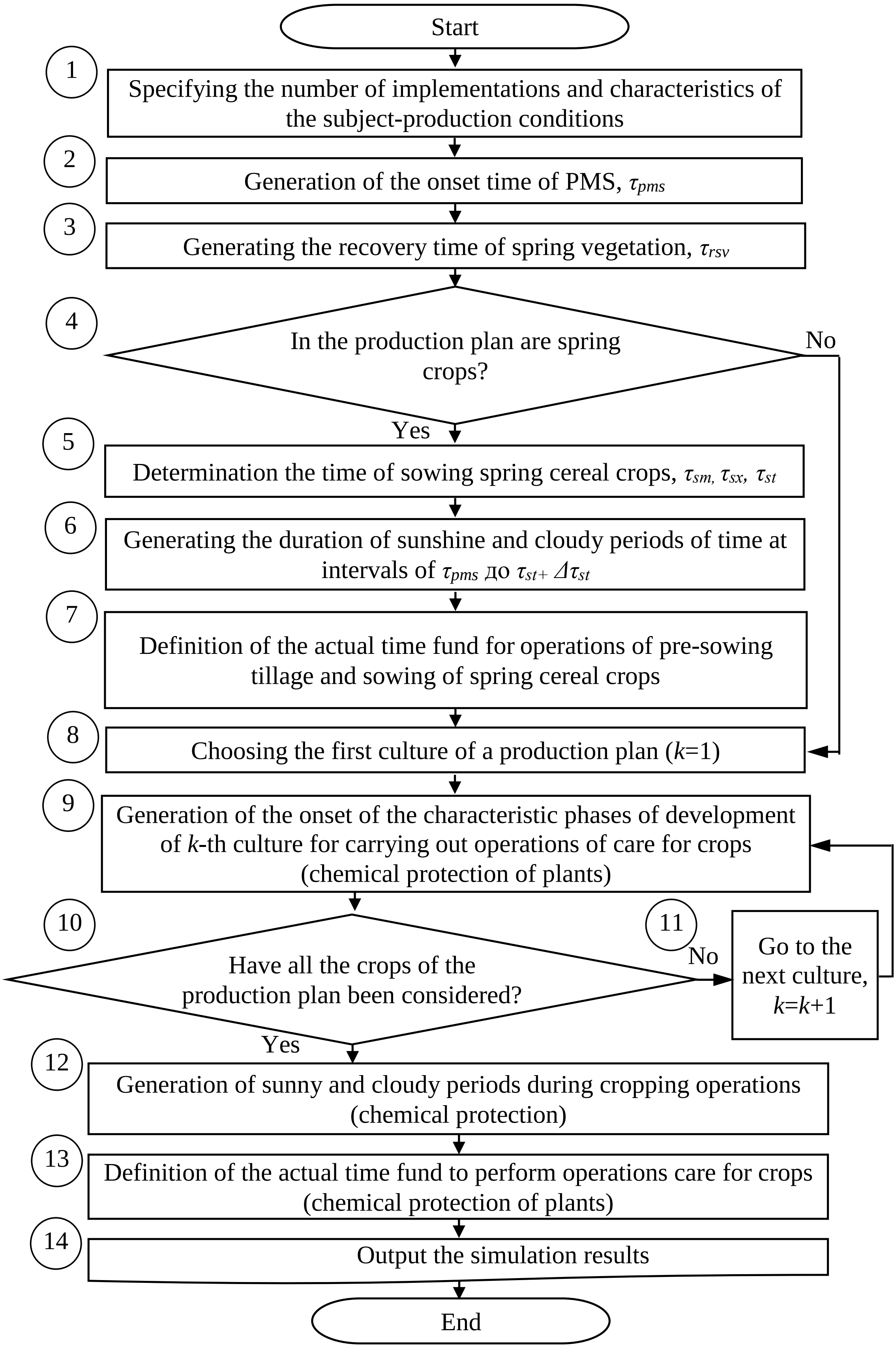
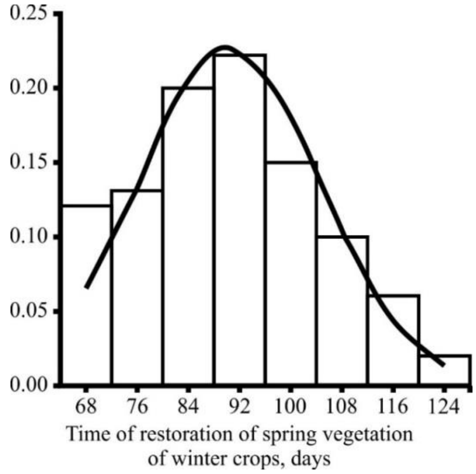


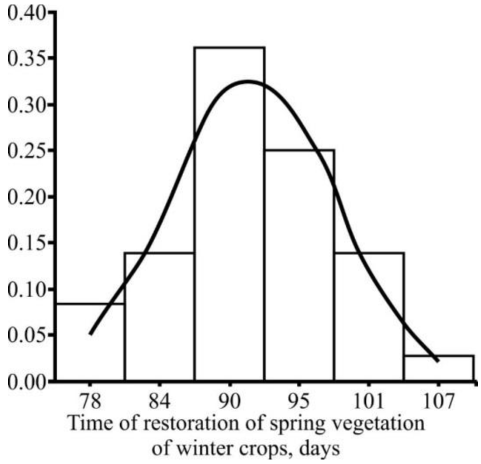
Fig. 1. Generalized algorithm for modeling the occurrence of subject-agrometeorological events in mechanized processes of arable farming in the spring-summer period.

$$f\left(\tau_{rsv}\right)=0,03\times\exp\left(-\frac{\left(\tau_{rsv}-90,32\right)^2}{202,6}\right)$$



a)

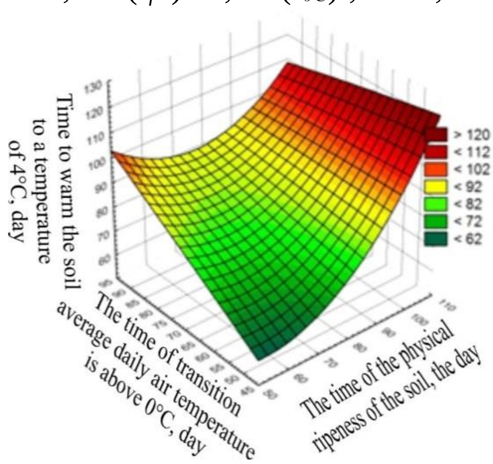
$$f\left(\tau_{rsv}\right)=0,04\times\exp\left(-\frac{\left(\tau_{rsv}-87,27\right)^2}{126,37}\right)$$



b)

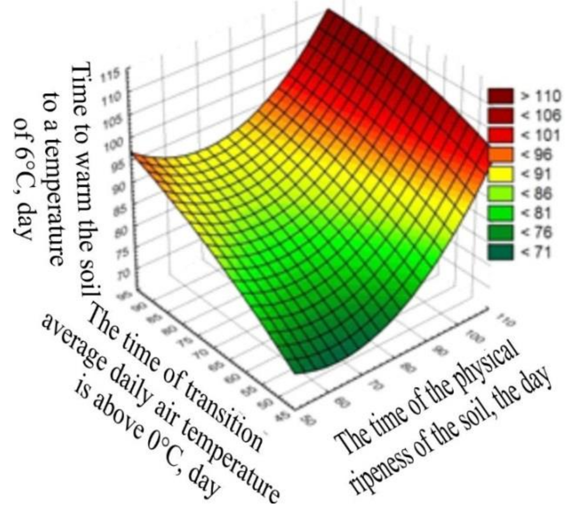
Fig. 2. Distribution of the time of restoration of spring vegetation of winter grains in agrometeorological conditions of L'viv (a) and Kherson (b) regions of Ukraine.

$$\tau_{4C} = 26,58 - 1,07\,\tau_f^{\,n} + 1,88\,\tau_{0C} - 0,019\,\tau_{0C}\cdot\tau_f^{\,n} + 0,019\,(\tau_f^{\,n})^2 - 0,001(\tau_{0C})^2;\ R^2=0,96$$



a)

$$\tau_{6C} = 78,05 + 1,51\,\tau_f^{\,n} + 1,21\,\tau_{0C} - 0,005\,\tau_{0C}\,\tau_f^{\,n} + 0,014\,(\tau_f^{\,n})^2 - 0,004(\tau_{0C})^2;\ R^2=0,87$$



b)

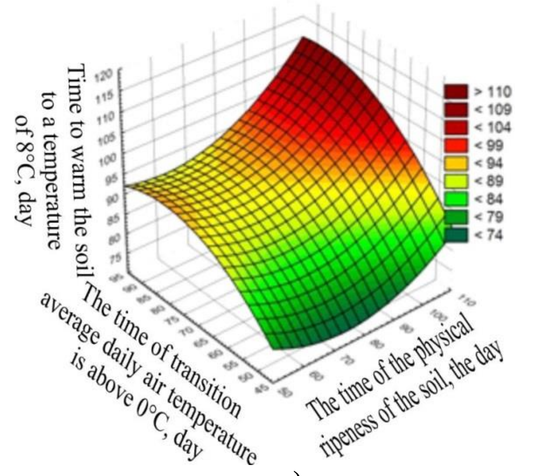
Fig. 3. Change in the duration of soil warming at a depth of 10 cm from the time of its physical maturity and the time of transition of the average daily temperature of air above 0°C in the spring to the temperature:

a) 4°C,

b) 6°C,

c) 8°C (for the conditions of the Lviv region of Ukraine)

$$\tau_{8C} = 68,44 - 1,46\,\tau_f^{\,n} + 1,87\,\tau_{0C} - 0,004\,\tau_{0C}\cdot\tau_f^{\,n} + 0,009\,(\tau_f^{\,n})^2 - 0,013(\tau_{0C})^2;\ R^2=0,57$$



c)

Fig. 3. Change in the duration of soil warming at a depth of 10 cm from the time of its physical maturity and the time of transition of the average daily temperature of air above 0°C in the spring to the temperature.

In the fourth stage (Figure 1), the presence of spring cereal crops in the production plan of the AP is checked. If spring crops are available, then proceed to stage 5, if not – go to step 8.

The fifth stage (Figure 1) provides for the calculation of the time of sowing of spring crops, which depends on the time of soil warming at a depth of 10 cm to the required temperature of crop sowing.

For its forecasting, regularities of the change in the duration of soil warming at 10 cm depth from the time of its physical maturity and the time of transition of the average daily temperature of air above 0 °C in the spring period to temperatures of 4 °C (possibility of sowing frost-resistant crops) were established, 6°C (possibility of sowing cold-resistant crops) and 8°C (possibility of sowing thermophilic cultures) for different regions of the state. In particular, for the agro-meteorological conditions of the L'viv region of Ukraine, the indicated dependencies presented in Figure 3. Next (stage 8) the first grain crop is selected from the given production plan of agricultural commodity producers, for which the time onset of phenological phases of development of plants is generated (step 9).

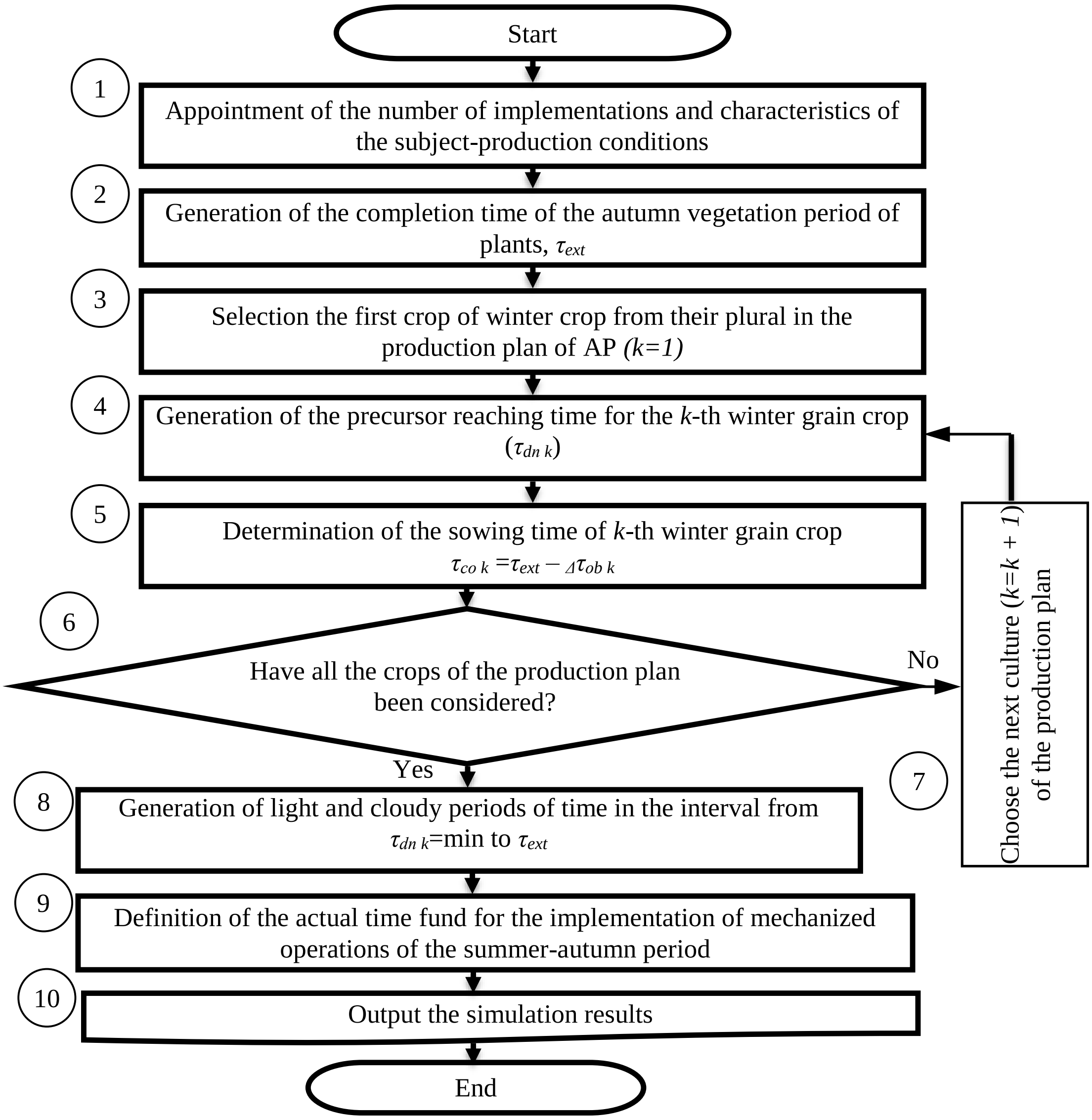


Fig. 4. A generalized algorithm for modeling the occurrence of subject-agrometeorological events in the technological processes of cultivation grain crops the summer-autumn period.

The dependence of the onset of the phenological phases of the development of spring and winter grains on, respectively, the time of their sowing and the restoration of spring vegetation (for the conditions the L'viv region of Ukraine) is disclosed in the paper [5]. At the tenth stage (Fig. 1) the condition is checked whether all crops of the production plan are considered. If not for all cultures, the time of the onset of the phenological phases of the development of plants is generated, the transition to the next culture (step 11) and the return to the stage 9 are carried out. If for all – we pass to the stage 12, on which (Figure 1) the appearance and duration of the algae and low season periods based on statistical regularities of their appearance and duration in the process of performing cropping operations (chemical protection of plants) for agrometeorological conditions of a given region of agricultural commodity producers [2, 10, 12].

The final stages of modeling the occurrence of subject-agrometeorological events in the technological processes of cultivation grain crops in the spring-summer period (Figure 1) is the definition of the actual time fund for the implementation of cropping operations (chemical protection of plants) (stage 13) and the output of the simulation results (stage 14).

The analysis of the technological processes of cultivation grain crops of summer-autumn period makes it possible to assert that the time constraints on their implementation depend on the timeliness of implementation of mechanized processes in the spring and summer period. In particular, the probabilistic nature of the timing of reaching winter crop precursors and the timeliness of harvesting their crops (spring-summer period) determine the need for pre-planting of the soil (summer-autumn period). The time for the pre-sowing cultivation of the soil is due to the need to sow winter crops. In turn, the need to sow winter cereals is determined by the conditions of their autumn vegetation.

Winter cereals are recommended to sow so that, before the beginning of winter, provide a set of plants with the required amount of effective daily average temperatures. Under such conditions, the crop manages to develop into the phase of planting and undergo quenching by the action of low temperatures, which is an important prerequisite for its wintering and productive development in the next spring vegetation [1, 4, 13]. The time interval between the completion of harvesting of the predecessor and the time of emergence of winter crop sowing needs is characterized by the timeframe for pre-sowing tillage in the summer-autumn period.

The influence of subject-agrometeorological events in the technological processes of cultivation grain crops the summer-autumn period cultivation on the formation of time-based funds for the implementation of individual operations of these processes has been taken into account and reflected in the algorithm for simulating the occurrence of these events in a separate day and during the season (Figure 4). In the first stage (Figure 4), the simulation of occurrence subject-agrometeorological events in the technological processes of the summer-autumn period justifies the number of implementations of the computer model to provide the necessary accuracy of the output data, as well as the characteristics of the natural and production conditions (geographical location and characteristics of the production plan of AP).

$$f(\tau_{ext}) = 0,075\left(\frac{\tau_{ext}-285}{25,131}\right)^{0,887}\exp\left[-\left(\frac{\tau_{ext}-285}{25,131}\right)^{1,887}\right]$$

$$f(\tau_{ext}) = 0,064\left(\frac{\tau_{ext}-294}{23,967}\right)^{0,545}\exp\left[-\left(\frac{\tau_{ext}-294}{23,967}\right)^{1,545}\right]$$

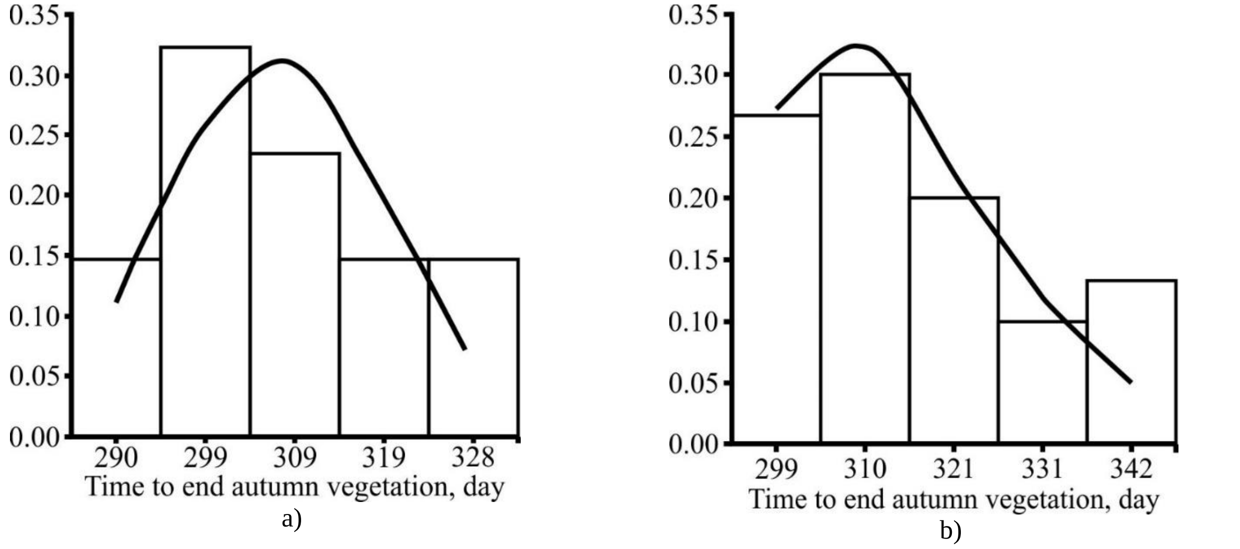


Fig. 5. Distribution of the time of completion of the autumn vegetation of winter grains in the agro-meteorological conditions of the Lviv (a) and Kherson (b) regions of Ukraine.

The next step (stage 2 of figure 4) is the generation of the end time of the autumn winter growth of winter crops. For this purpose, the distributions of the time of completion of the autumn winter vegetation period of winter crops in the agro-meteorological conditions of all regions of Ukraine were constructed and their statistical characteristics were determined. It was established that the distribution of the time of completion of the autumn vegetation period of winter grain crops is consistent with the theoretical law of the distribution of Weibull (Figure 5).

For example, an estimation of the mathematical expectation of the completion time of the autumn vegetation duration for the conditions of the Lviv region of Ukraine $\bar{M}[\tau_{ext}] = 307,3\,\text{days}$, and the mean square deviation $\bar{\sigma}[\tau_{ext}] = 12,2\,\text{days}$ (Figure 5, a). For conditions of the Kherson region of Ukraine $\bar{M}[\tau_{ext}] = 315,6\,\text{days}$, $\bar{\sigma}[\tau_{ext}] = 14,1\,\text{days}$ (figure 5, b).

The third stage (Figure 4) assumes the choice of the first winter crop ($k = 1$) from the given production plan of the agricultural producer, and the next (stage 4) generates the time of reaching the predecessor ($\tau_{dn\,k}$) for the k winter crop. For this purpose, the statistical characteristics of the time distribution of the achievement of characteristic predecessors of winter grain crops in agrometeorological conditions of all regions of Ukraine were determined. For comparison, the statistical characteristics of the time distribution of the characteristic predecessors of winter cereal crops in the agro-meteorological conditions of the L'viv and Kherson regions of Ukraine shown in Table. 2

At stage 5 (Figure 4), the time of sowing of the *k*-th winter grain crop ($\tau_{co\,k}$) is determined, taking into account the condition of its recruitment of the required amount of active temperatures until the end of autumn vegetation:

$$\tau_{co\,k} = \tau_{ext} - \Delta\tau_{obk}\,, \quad (1)$$

where: $\Delta\tau_{obk}$ – the term for which the winter culture will collect the required amount of active temperatures.

At stage 6 (Figure 4), an examination is made of whether all winter crops of the farmer’s production plan are considered. If so, go to the next stage 8, if not - select the next culture (stage 7) and return to stage 4.

The eighth stage (Figure 4) provides for the generation of weathered and cloudy periods of time during a period of time from reaching predecessor of a given winter crop until the end of the autumn vegetation period of the given winter crop.

These intervals are generated on the basis of statistical regularities of their appearance and duration in the specified period for the conditions of a given region [2, 10, 12].

At stage 9 (figure 4), based on the information received earlier, the actual time frame for performing mechanized operations for each crop is determined, as well as the tense periods of their implementation. Finally, the output of the obtained simulation results is performed (stage 10, figure 4).

Table 2. Statistical characteristics of the time distribution of the achievement of characteristic predecessors of winter cereal crops.

Indexes	Distribution density function	M[t], day	σ[t], day
L’viv region			
Date of the set of 1200°C of active temperatures (roughly, reaching the winter barley, winter rye)	$f\left(t_{1200}\right)=0,05\times\exp\left(-\frac{\left(t_{1200}-180,7\right)^2}{109,52}\right)$	180,7	7,4
Date of the set of 1500°C of active temperatures (roughly, reaching the potatoes)	$f\left(t_{1500}\right)=0,01\times\exp\left(-\frac{\left(t_{1500}-197,2\right)^2}{100,6}\right)$	197,2	7,1
Date of the set of 1700°C of active temperatures (roughly, reaching the oats)	$f\left(t_{1700}\right)=0,05\times\exp\left(-\frac{\left(t_{1700}-208,2\right)^2}{115,52}\right)$	208,2	7,6
Date of the set of 2200°C of active temperatures (roughly, reaching the corn for silage)	$f\left(t_{2200}\right)=0,01\times\exp\left(-\frac{\left(t_{2200}-235,2\right)^2}{182}\right)$	235,3	9,0
Kherson region			
Date of the set of 1200°C of active temperatures (roughly, reaching the winter barley, winter rye)	$f\left(t_{1200}\right)=0,08\times\exp\left(-\frac{\left(t_{1200}-167,7\right)^2}{56,18}\right)$	167,7	5,3
Date of the set of 1500°C of active temperatures (roughly, reaching the potatoes)	$f\left(t_{1500}\right)=0,08\times\exp\left(-\frac{\left(t_{1500}-182,3\right)^2}{54,8}\right)$	182,3	5,2
Date of the set of 1700°C of active temperatures (roughly, reaching the oats)	$f\left(t_{1700}\right)=0,07\times\exp\left(-\frac{\left(t_{1700}-191,2\right)^2}{58,32}\right)$	191,2	5,4
Date of the set of 2200°C of active temperatures (roughly, reaching the corn for silage)	$f\left(t_{2200}\right)=0,06\times\exp\left(-\frac{\left(t_{2200}-212,2\right)^2}{83,1}\right)$	212,6	6,5

Thus, the developed scientific and methodological principles of modeling of subject-agrometeorological events in the technological processes cultivation grain crops fully take into account the peculiarities of the course of these processes in the spring-summer and summer-autumn periods, the regularities of the appearance of subject-agrometeorological events and their influence on the formation of funds for the time of mechanized operations.

Conclusions

1. The analysis of subject-agrometeorological events in the technological processes cultivation grain crops made it possible to classify them in terms periodicity of appearance, as well as to indicate the content of the influence of each of them on the course of these processes, which made possible the development of algorithms for simulating the occurrence of these events in these processes.

2. The statistical characteristics of the distribution of the time of the restoration of spring vegetation, the completion of the autumn winter vegetation period of winter crops, the time to reach their characteristic predecessors, as well as the regularities of the change in the duration of soil warming in different agrometeorological conditions of the regions of Ukraine, make it possible to predict (generate) the onset of phases of plant development and time Restrictions on the implementation of mechanized operations in the technological processes cultivation grain crops in the

specified natural and production conditions of individual agricultural of the commodity producers.

3. The developed scientific and methodological principles of modeling of subject-agrometeorological events in the technological processes cultivation grain crops are the basis for the creation of their computer models, the practical use of which will enable to predict time limits for the implementation of technological processes and the characteristics of orders flows for their implementation.

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МЕТОДИЧНІ ОСНОВИ МОДЕЛЮВАННЯ ПРЕДМЕТНО-АГРОМЕТЕОРОЛОГІЧНИХ ПОДІЙ В ТЕХНОЛОГІЧНИХ ПРОЦЕСАХ НА ВИРОЩУВАННІ ЗЕРНОВИХ КУЛЬТУР

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Анотація. У статті відзначено і класифіковані предметно-агрометеорологічні події в технологічних процесах на вирощуванні зернових культур, встановлено статистичні характеристики розподілів часу виникнення і тривалості цих подій, розкрито методичні засади та розроблено алгоритми їх моделювання. Під час досліджень були використані методи аналізу і синтезу, системно-факторних і системно-подійних підходів до дослідження технологічних процесів при вирощуванні зернових культур. Для розробки алгоритмів моделювання цих технологічних процесів були використані дискретно-подійний підхід. Проведений аналіз предметно-агрометеорологічних подій в технологічних процесах при вирощуванні зернових культур дозволив класифікувати їх за часом і періодичністю появи, а також визначити зміст впливу кожної з них на хід цих процесів, що дозволило розробки алгоритмів моделювання виникнення зазначених подій у вищевказаних технологічних процесах. Встановлені статистичні характеристики розподілів часу відновлення весняної вегетації, завершення тривалості осінньої вегетації озимих зернових культур, часу дозрівання їх характерних попередників, а також закономірності зміни тривалості прогріву грунту в різних агрометеорологічних умовах регіонів України дозволяють прогнозувати (генерувати) настання фаз розвитку рослин і тимчасові обмеження на виконання механізованих операцій у технологічних процесах рільництва при заданих природно-виробничих умов окремих сільськогосподарських товаровиробників. Розроблені науково-методичні основи моделювання предметно-агрометеорологічних подій в технологічних процесах рільництва лежать в основі їх створення комп’ютерних моделей в технологічних процесах рільництва, практичне використання яких дозволить прогнозувати часові обмеження виконання механізованих операцій та характеристики потоків замовлень на їх виконання.

Ключові слова: предметно-агрометеорологічні події, технологічні процеси землеробства, механізовані операції, моделювання.

МЕТОДИЧЕСКИЕ ОСНОВЫ МОДЕЛИРОВАНИЯ ПРЕДМЕТНО-АГРОМЕТЕОРОЛОГИЧЕСКИХ СОБЫТИЙ В ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССАХ НА ВЫРАЩИВАНИИ ЗЕРНОВЫХ КУЛЬТУР

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Аннотация. В статье отмечено и классифицированы предметно-агрометеорологические события в технологических процессах на выращивании зерновых культур, установлено статистические характеристики распределений времени возникновения и продолжительности этих событий, раскрыто методические основы и разработаны алгоритмы их моделирования. Во время исследований были использованы методы анализа и синтеза, системно-факторных и системно-событиевых подходов к исследованию технологических процессов при выращивании зерновых культур. Для разработки алгоритмов моделирования этих технологических процессов были использованы дискретно-событиевый подход. Проведенный анализ предметно-агрометеорологических событий в технологических процессах при выращивании зерновых культур позволил классифицировать их по времени и периодичностью появления, а также обозначить содержание влияния каждой из них на ход этих процессов, что позволило разработки алгоритмов моделирования возникновения указанных событий в вышеуказанных технологических процессах. Установлены статистические характеристики распределений времени возобновления весенней вегетации, завершение продолжительности осенней вегетации озимых зерновых культур, времени созревания их характерных предшественников, а также закономерности изменения продолжительности прогрева почвы в различных агрометеорологических условиях регионов Украины позволяют прогнозировать (генерировать) наступления фаз развития растений и временные ограничения на выполнения механизированных операций в технологических процессах полеводства при заданных природно-производственных условий отдельных сельхозтоваропроизводителей. Разработанные научно-методические основы моделирования предметно-агрометеорологических событий в технологических процессах полеводства лежат в основе создания их компьютерных моделей в технологических процессах полеводства, практическое использование которых позволит прогнозировать временные ограничения выполнения механизированных операций и характеристики потоков заказов на их выполнение.

Ключевые слова: предметно-агрометеорологические события, технологические процессы земледелия, механизированные операции, моделирование.

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