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СУТОЧНЫЕ КОЛЕБАНИЯ ДИАМЕТРА СТЕБЛЯ ТОМАТА КАК КРИТЕРИЙ УПРАВЛЕНИЯ ПОЛИВОМ

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Рассмотрен процесс суточного изменения диаметра стебля томата с целью обоснования использования этого параметра для управления капельным орошением. Изменение размеров отдельных частей растений зависит от обеспечения продукционного процесса водой, светом, теплом и элементами питания. Поэтому такие параметры растений, как температура листьев, скорость потока ксилемы, диаметр плода и стебля, могут быть индикаторами наличия необходимых ресурсов. Исследования проведены в Новосибирской области в июне – сентябре 2020 г. В качестве индикатора водного стресса растений использована величина диапазона суточных колебаний диаметра стебля, которая имеет тесную связь с относительной влажностью почвы. Источником информации послужили результаты измерений влажности почвы и прироста диаметра стебля томата. Эксперименты по оценке влияния водного дефицита на параметры стебля проводили на растении, высаженном в открытый грунт отдельно от остальных. Условия искусственного водного стресса создавали путем полива один раз в неделю. Сбор данных осуществляли с помощью фитомонитора РМ-11z, датчиков влажности почвы и диаметра роста стебля. Результаты измерений обрабатывали в программе Microsoft Office Excel. Установлено, что диапазон суточных колебаний прироста диаметра стебля зависит от наличия влаги. При влажности почвы ниже 30% растение испытывает водный стресс и диапазон колебаний диаметра стебля увеличивается. Максимальный рост диаметра стебля наблюдался в 7–10 ч, минимальный – в 13–15 ч местного времени. Разница между максимумом и минимумом суточного прироста диаметра стебля характеризует диапазон суточной разницы диаметра стебля, который тесно коррелирует с влажностью почвы. Коэффициент корреляции между ними составляет 0,72. Предельное значение суточной разницы диаметров стеблей составляет 0,025 мм при влажности почвы 30%. Превышение фактического значения этого параметра граничного значения может служить сигналом к включению системы орошения. Реализация данного подхода дает возможность автоматизировать технологический процесс полива и учесть показатель, сигнализирующий о водном стрессе растения.

Ключевые слова: продукционный процесс, диаметр стебля, водный стресс, фитомониторинг, датчик, полив

DAILY VARIATIONS IN TOMATO STEM DIAMETER AS A CRITERION FOR IRRIGATION MANAGEMENT

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The process of daily variation in tomato stem diameter is examined in order to justify the use of this parameter to control drip irrigation. Changes in the size of individual plant parts depend on the provision of water, light, heat and nutrients to the production process. Therefore, such plant parameters as leaf temperature, xylem flow rate, fruit and stem diameter can be indicators of availability of necessary resources. The research was carried out in Novosibirsk region in June - September 2020. The value of the range of daily variations in stem diameter, which has a close relationship to relative soil moisture, was used as an indicator of plant water stress. The source of the information is the results of measurements of soil moisture and stem diameter growth of tomato. Experiments to assess the effect of water deficit on stem parameters were carried out on a plant set out in the open ground separately from the rest. Artificial water stress conditions were created by

watering once a week. Data were collected using a PM-11z phytomonitor, soil moisture and stem diameter growth sensors. The results of measurements were processed in Microsoft Office Excel program. It was found that the range of daily fluctuations of stem diameter growth depends on moisture availability. When soil moisture is below 30%, the plant experiences water stress and the range of stem diameter fluctuations increases. The maximum growth in stem diameter was observed at 7-10 a.m. and the minimum at 13-15 p.m. local time. The difference between the maximum and minimum of the daily stem diameter increase characterizes the range of the daily stem diameter difference, which correlates closely with soil moisture. The correlation coefficient between them is 0.72. The limit for the daily stem diameter difference is 0.025 mm at 30% soil moisture. If the actual value of this parameter exceeds the limit value, the irrigation system can be activated. The implementation of this approach makes it possible to automate the irrigation process and to take into account the indicator that signals water stress of the plant.

Keywords: production process, stem diameter, water stress, phytomonitoring, sensor, irrigation

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INTRODUCTION

The productivity of agricultural plants is the result of a complex of natural processes that depend on the habitat. Negative effects of these influences are compensated by technological processes. The efficiency of cultivation depends on the correct and timely execution of all technological operations for crop cultivation. Currently, most research is focused on the application of high-tech controls for production processes and individual operations [1-3].

The basis for deciding whether or not to carry out a technological operation is information obtained by observing natural processes, the experience and intuition of plant specialists. The right choice of technological operation and its timing depends largely on the human factor. Reducing this dependence is one of the challenges that cannot be met without the digitalization of crop technology.

According to the laws of farming, the maximum yield can be obtained when all crop conditions are optimally combined. The limiting factor when growing tomatoes in Siberian conditions is heat. Application of cultivation facilities during the whole period of vegetation increases the air temperature in the zone of plant growth, so the next limiting factor is moisture supply [4-6]. Consequently, the timing of irrigation is an important condition for obtaining high yields of tomatoes.

The purpose of the study is to justify the choice of the parameter of daily variation of the tomato stem diameter as a criterion for assessing the necessity of performing the technological process of irrigation.

MATERIAL AND METHODS

The plant production process consists of photosynthesis and processes of organic matter transfer from leaves to other organs by xylem fluxes. The specificity of ecological and physiological studies is that the plant is considered as a single organism, the vital functions of which are closely interrelated and are implemented in constant interaction with changing environmental factors [7, 8]. Changes in the size of plant parts such as the stem and fruit depend on the provision of the production process with water, light, heat and nutrients. Such plant parameters as leaf temperature, xylem flux rate, fruit and stem diameter can be indicators of the availability of the necessary resources in the production process [9-11].

Daily variation measures in the stem diameter is an important indicator of water availability. Many factors influence the water requirements of plants: soil, climatic, physiological parameters of plants. Complex consideration of such parameters in the mathematical model allows solving the problem of operational control of drip irrigation systems [12-14]. The boundary conditions of the necessity of the irrigation operation are required to be determine for practical use of these parameters. The set problems are solved experimentally by measuring the increment of stem diameter of tomato at change of humidity of soil. The experiment was conducted in the Novosibirsk region from June 16 to September 10, 2020. A plant planted in the open ground separately from the others was used to assess the effect of water stress on stem parameters. Conditions of artificial water stress were created by watering once a week. The use of special modern phytomonitor systems and equipment (photosynthesis monitor RTM-48A and phytomonitor PM-11z [15] to study the variability and diversity of changes in the characteristics of CO2-gas exchange in response to environmental changes) allowed us to identify the optimal and threshold values of abiotic factors limiting the growth and development of plants [16].

An SMTE-3z soil sensor was placed in the rooting zone of the plant at a depth of 10-20 cm. It measured the temperature, humidity and electrical conductivity of the soil. The stem diameter growth sensor SD-5z was installed on the lower part of the stem to record the change in stem size relative to its diameter at the time of installation. The resolution was at least 0.002 mm. The fruit diameter sensor measured the actual fruit diameter. The resolution was at least 0.04 mm.

The sensor signals are transmitted via the radio module to the phytomonitor, stored in its memory and used for further computer processing. The interval for collecting sensor information is 15 minutes. The complex operates continuously throughout the vegetation period.

A DWS-11z weather station was used to measure environmental characteristics, and phytomonitoring sensors were used for plant and habitat characteristics (see Figure 1).

RESULTS AND DISCUSSION

The results of measurements of fruit diameter, stem growth and soil moisture are shown graphically in Figure 2. The graph shows that the limit value for soil moisture under the conditions of the experiment is a moisture content of about 30%. But this parameter can significantly depend on the mechanical composition of the soil and its other properties. Therefore, the reaction of the plant to changes in its moisture content is the most reliable criterion for assessing the need for the technological process of irrigation.

The stem diameter growth curve has two extremes daily: a maximum in the morning and a minimum in the afternoon. The maximum stem diameter increase was observed at 7-10 h and the minimum at 13-15 h local time. The difference between the maximum and minimum (hereafter referred to as the stem diameter difference) is a characteristic of the range of daily

Рис. 1. Приборы для измерения параметров растений и внешней среды обитания:
1 – почвенный датчик, *2* – датчик прироста диаметра стебля, *3* – датчик диаметра плода, *4* – радиомодуль

Fig. 1. Instruments for measuring the parameters of plants and the external environment:
1 – soil sensor, *2* – stem diameter growth sensor, *3* – fruit diameter sensor, *4* – radio module

variations in stem diameter, which is closely correlated with soil moisture. The correlation coefficient between the two is 0.72.

The dynamics of the soil moisture and stem diameter difference is shown in Fig. 3. The graph shows that there is an inversely proportional relationship between the soil moisture and the variation in stem diameter, as the variations occur in counter-phase. With a soil moisture of 30% the swing of the stem diameter is about 0.025 mm. Hence, it can be assumed that a stem diameter difference greater than 0.025 mm is a sign of tomato water stress. However, this assumption requires further testing and clarification of the effect of the plant age and other conditions.

CONCLUSION

An indicator of the presence of water stress in tomatoes is the amount of daily variation in stem diameter. The stem diameter difference, i.e. the difference between the morning maximum and the daily minimum of stem diameter growth, can be used as an indicator of plant water stress to control irrigation systems in digital tomato cultivation technology. According to the results of the study, the limit value of the stem diameter difference is 0.025 mm. Exceeding the actual value of this limit value parameter can serve as a signal to activate the irrigation system.

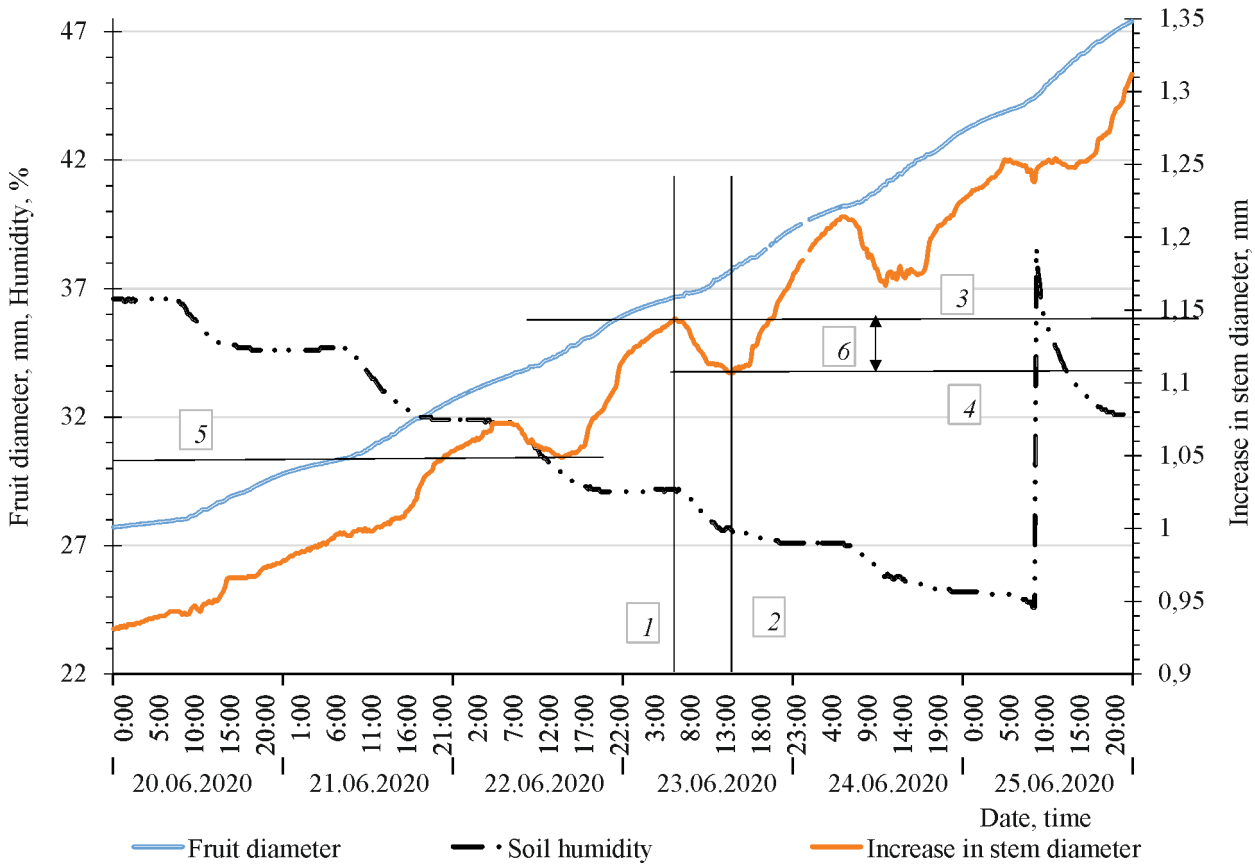

Рис. 2. Динамика изменения параметров почвы и растения при недостатке влаги

1 – время утреннего максимума, *2* – время дневного минимума, *3* – значение утреннего максимума, *4* – значение дневного минимума, *5* – допустимый минимум влажности почвы

Fig. 2. Dynamics of changes in soil and plant parameters with a lack of moisture

1 – time of the morning maximum, *2* – time of the daytime minimum, *3* – value of the morning maximum, *4* – value of the daytime minimum, *5* – permissible minimum soil moisture

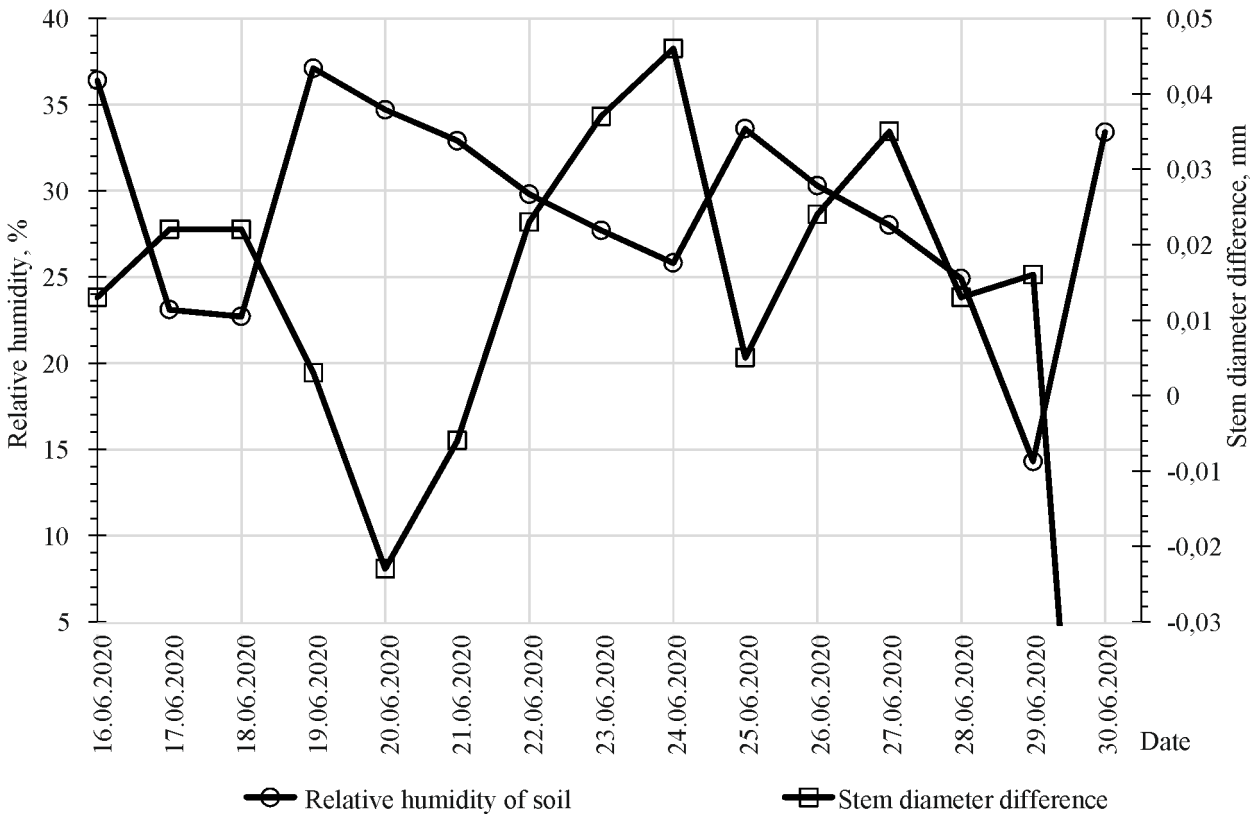

Рис. 3. Динамика изменения влажности почвы и перепада диаметра стебля
Fig. 3. Dynamics of changes in soil moisture and the difference in stem diameter

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