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Article

Detection and Assessment of Melon Diseases and Pests Using Electronic Software for Digital Analysis

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Abstract: This article addresses the detection and analysis of the main diseases and pests occurring on the melon (Cucumis melo L.) crop, and the assessment of the degree of damage, by means of digital technologies. The possibilities of using artificial intelligence, machine learning and computer vision algorithms for detecting, on the basis of digital images, the pathological changes observed on the leaves, stems and fruits of the melon plant are considered. In particular, a mechanism is proposed for the software-based diagnosis of powdery mildew, Fusarium wilt, downy mildew and anthracnose, as well as of pests such as the melon fly, aphids and spider mites. The scientific and methodological foundations of image processing, determination of the damaged area, classification of diseases and pests, and specification of protection measures by means of electronic software have been developed.

Keywords: melon, disease, pest, digital diagnostics, artificial intelligence, electronic software, computer vision, powdery mildew, Fusarium wilt, melon fly, digital monitoring.

Introduction

Melon (Cucumis melo L.) is one of the important melon-and-gourd crops of Uzbekistan and is of particular importance in ensuring food security, increasing export potential and raising the economic efficiency of agricultural production. The natural and climatic conditions of our republic are favorable for growing various melon cultivars.

However, various diseases and pests have a negative effect on the growth and development of the melon crop. In particular, powdery mildew, Fusarium wilt and other fungal diseases reduce the assimilation surface of the plant and affect the quantity and quality of the yield [1].

In the studies of R.A. Xakimov and M.U. Xalimova, it was noted that powdery mildew and Fusarium wilt are among the important phytopathological problems in melon cultivation in Uzbekistan [2].

In addition, the melon fly (Carpomyia pardalina Bigot) is considered one of the pests that cause serious damage to melon fruits. As a result of the development of larvae in damaged fruits, the marketable quality of the product decreases and it may become unfit for consumption [3].

In traditional diagnostic methods, the detection of diseases and pests is based on the field observations and laboratory examinations of specialists. Such an approach may require a great deal of time and may make monitoring work difficult, especially over large areas [4].

At present, the possibilities for automatic detection of plant diseases are expanding through the use of artificial intelligence, digital image processing and machine learning technologies [5][6]. These technologies make it possible to detect color changes, spots, necrosis, deformation and damage caused by pests on plant organs [7].

For this reason, developing electronic software for the digital analysis of melon diseases and pests and using it in practice is a topical scientific and practical task [8].

The aim of the research is to improve the scientific and methodological foundations of developing an electronic software system that detects diseases and pests occurring on the melon crop on the basis of digital images, assesses the degree of damage, and gives scientifically grounded recommendations for combating them.

Research objectives:

- to identify the main species of melon diseases and pests;
- to form a digital image database of healthy and damaged plant organs;
- to classify the signs of diseases and pests on the basis of digital images;
- to develop a diagnostic model using artificial intelligence algorithms;
- to quantitatively assess the degree of damage of melon organs;
- to form recommendations on protection measures on the basis of the diagnostic results;
- to substantiate the possibilities of testing the electronic software under field conditions [9].

Materials and Methods

The diseases and pests occurring on the melon crop and the morphological changes arising in plant organs under their influence are selected as the object of the research.

The subject of the research consists of methods of detecting melon diseases and pests by means of digital images, assessing the degree of damage, and forming diagnostic results in an electronic database.

The following methods are envisaged for use in the research process:

1. **Field observation method.** Observing the signs of diseases and pests on the leaves, stems and fruits of plants during the vegetation period of the melon crop.
2. **Digital photography method.** Photographing healthy and damaged plant organs using a mobile phone or a digital camera.
3. **Image processing method.** Standardizing the images obtained, normalizing color and contrast indicators, and separating the damaged areas.
4. **Machine learning method.** Forming a model for automatic classification on the basis of images of melon diseases and pests.
5. **Deep learning method.** Detecting disease signs and pest objects by means of CNN and YOLO algorithms.
6. **Mathematical-statistical method.** Assessing the accuracy, sensitivity and classification effectiveness of the diagnostic model.

Formation of an electronic database of melon diseases and pests

In the electronic software, it is first required to create a classified database of the main diseases and pests of the melon crop.

Table 1. Main diseases occurring on the melon crop and their digital diagnostic signs

№	Disease name	Causal agent	Main signs in the digital image
1	Powdery mildew	Podosphaera xanthii and Golovinomyces spp.	White powdery coating on the leaf surface
2	Fusarium wilt	Fusarium oxysporum f. sp. melonis	Yellowing and wilting of leaves
3	Downy mildew	Pseudoperonospora cubensis	Angular yellow spots on leaves
4	Anthracnose	Colletotrichum orbiculare	Dark necrotic spots on leaves and fruits
5	Root collar rot	Rhizoctonia solani and other pathogens	Blackening and rotting at the root collar

Some signs of diseases may be similar to one another. Therefore, verified images, the biological characteristics of the disease and its diagnostic signs must be attached for each disease in the electronic database.

Table 2. Melon pests and the signs for their digital detection

№	Pest name	Scientific name	Signs in the digital image
1	Melon fly	Carpomyia pardalina	Egg-laying marks on the fruit, larval damage and rot
2	Melon aphid	Aphis gossypii	Small insects accumulated on the underside of the leaf, leaf curling
3	Spider mite	Tetranychus urticae	Small whitish dots and fine webbing on the leaf
4	Whitefly	Bemisia tabaci	Small white insects accumulated on the underside of the leaf
5	Thrips	Thrips spp.	Silvery spots and damage on the leaf surface

This classification serves to form the initial database for the software. To identify pests at the exact species level, images at sufficient magnification and entomological examinations are required.

Results and Discussion

Mechanism for digital detection of melon diseases by means of electronic software

The proposed electronic software is intended to receive from the user a photograph of the damaged organ of the melon plant and to analyze it automatically [10].

It is proposed that the software operate in the following sequence:

Stage 1. Uploading the image to the software.

The user uploads a photograph of the melon leaf, stem or fruit to the software by means of a mobile phone or computer. Information on the crop cultivar, plant age, vegetation stage, region and observation date is attached to the image.

Stage 2. Image processing.

The quality of the uploaded image is checked. Brightness and contrast indicators are normalized, and the image size is standardized [11].

Stage 3. Detection by means of artificial intelligence.

The image is passed to a pre-trained neural network model. The model identifies the visual signs in the image that are characteristic of a disease or pest.

Stage 4. Assessment of the degree of damage.

After the disease signs are detected, the ratio of the damaged area to the total leaf surface is calculated.

Formula for determining the degree of damage of the leaf:

$$Z = (S_1 / S_2) \times 100$$

Where:

Z – degree of damage of the leaf, %;

S_1 – leaf surface damaged by the disease, cm^2;

S_2 – total surface of the leaf, cm^2.

For example, if the total surface of a melon leaf is 80 cm^2 and the damaged part is 16 cm^2:

$$Z = (16 / 80) \times 100 = 20\%.$$

Thus, 20 percent of the surface of this leaf is damaged by disease signs.

Stage 5. Forming the diagnostic conclusion.

The software provides information on the name of the detected disease or pest, the reliability of the classification, the degree of damage and the recommended further examinations.

Stage 6. Electronic monitoring.

The diagnostic results are saved in the electronic database. By means of these data, it becomes possible to observe the spread of diseases and pests in melon fields by time and region.

Functional structure of the electronic software for analyzing melon diseases and pests

The proposed software may consist of the following main modules:

Table 3. Modules of the electronic software and their functions

№	Software module	Functional task
1	Home page	Information about the software and the main menu
2	Melon data	Cultivar, cropped area and vegetation period
3	Disease database	Disease types and diagnostic signs
4	Pest database	Insects and their damage signs
5	Digital diagnostics	Automatic detection by photograph
6	Damage analysis	Calculation of the damaged surface
7	Protection recommendations	Control and prevention measures
8	Monitoring	Saving results by time and region
9	Report	Forming electronic reports

Mathematical assessment of the digital diagnostic model

In determining the effectiveness of the electronic software, the correct and incorrect classification results of the model are taken into account [12].

Overall accuracy:

$$Accuracy = (TP + TN) / (TP + TN + FP + FN) \times 100$$

$$Precision = TP / (TP + FP)$$

$$Recall = TP / (TP + FN)$$

$$F1 = 2 \times (Precision \times Recall) / (Precision + Recall)$$

Where:

- TP – correctly detected disease cases;
- TN – correctly detected healthy cases;
- FP – incorrectly identifying a healthy object as diseased;
- FN – incorrectly identifying a diseased object as healthy.

These indicators must be calculated separately for each type of disease and pest, because the diagnostic characteristics of the algorithm for detecting the melon fly and the algorithm for detecting powdery mildew are not the same.

Determining measures to combat melon diseases by means of the electronic software

One of the important functions of the software product is to form practical recommendations for the detected diseases and pests [13].

Table 4. Protection measures recommended on the basis of digital diagnostic results

Disease or pest	Recommended protection measures
Powdery mildew	Selecting resistant cultivars, destroying diseased plant residues and, where necessary, using permitted fungicides
Fusarium wilt	Healthy seed, crop rotation, resistant cultivars and agrotechnical measures
Downy mildew	Field monitoring, managing the irrigation regime and, when the disease is confirmed, applying appropriate protection measures
Anthracnose	Healthy seed, crop rotation, destroying damaged residues
Melon fly	Pheromone or other monitoring means, collecting and destroying damaged fruits, agrotechnical and biological control
Melon aphid	Protecting beneficial entomophages, monitoring the degree of damage and, where necessary, using selective preparations
Spider mite	Regular field observation, biological control and, where necessary, using registered acaricides

When recommending chemical protection agents, their current registration for use on the melon crop, application rate, treatment timing and the waiting period before harvest must be taken into account [14].

Prospects for introducing the electronic software into production

This software product can be directed toward use in farms growing melons, agroclusters, scientific research institutions and plant protection organizations.

The use of the software creates the following practical opportunities:

- detecting melon diseases at an early stage;
- rapid monitoring of the spread of pests;
- quantitative assessment of damaged plant organs;
- forming an electronic database on diseases and pests;
- delivering rapid diagnostic information to farmers and agronomists;
- planning protection measures on a scientific basis;
- forming regional maps of the spread of diseases and pests.

It is advisable to create the software product initially in the form of an Android mobile application or a web platform, and later to integrate it with GPS and geographic information systems.

In developing the software model, 70 percent of the data can be allocated for training, 15 percent for validation and 15 percent for independent testing. In this case, similar photographs taken from one plant must not fall into different sets. The final model should also be tested using images from another field and season [15].

Conclusion

Developing electronic software for the digital analysis of melon diseases and pests is considered one of the promising directions for improving phytosanitary monitoring in melon growing and introducing modern digital technologies into practice.

The following scientific and practical conclusions were formed as a result of the research: There are possibilities of detecting, on the basis of digital images, the diseases occurring on the melon crop, such as powdery mildew, Fusarium wilt, downy mildew and anthracnose, and pests such as the melon fly, melon aphid and spider mite. The electronic software should contain modules for a database of diseases and pests, image processing, automatic diagnostics, calculation of the degree of damage and formation of protection recommendations. By assessing the degree of damage of melon leaves on the basis of digital images, the dynamics of disease development can be analyzed quantitatively. The use of artificial intelligence and computer vision algorithms makes it possible to automate the process of initial detection of diseases and pests. In assessing the effectiveness of the electronic software, it is necessary to compare the diagnostic results with the conclusions of phytopathologist and entomologist specialists. In the future, testing the software product in farms growing melons and expanding the image database for local cultivars will increase its practical significance.

In general, developing and introducing into practice electronic software for the digital analysis of melon diseases and pests may serve to increase the effectiveness of rapid diagnostics, monitoring and scientifically grounded decision-making in the plant protection system.

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