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Article

Detection and Assessment of Diseases and Pests of Quince (Cydonia Oblonga Mill.) Using Electronic Software for Digital Analysis

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Abstract: The article addresses the detection and analysis of diseases and pests occurring on quince (Cydonia oblonga Mill.) fruit trees, and the assessment of the degree of damage, on the basis of modern digital technologies. The possibilities of using artificial intelligence, machine learning and computer vision algorithms for detecting, by means of digital images, the pathological changes observed on the leaves, shoots, flowers and fruits of the quince tree are substantiated. In particular, a mechanism is proposed for detecting leaf spot (Diplocarpon mespili), moniliosis, fire blight (Erwinia amylovora), powdery mildew diseases, as well as codling moth, aphids, scale insects and other pests by means of electronic software. The functional modules of the software system, the digital database, the image processing algorithms and the mathematical methods for assessing the degree of damage are substantiated for development. This approach serves to improve phytosanitary monitoring in quince orchards and to organize plant protection measures in a timely manner.

Keywords: Quince, Cydonia oblonga Mill., disease, pest, digital diagnostics, artificial intelligence, electronic software, computer vision, leaf spot, moniliosis, fire blight, phytosanitary monitoring.

Introduction

Quince (Cydonia oblonga Mill.) is a fruit tree belonging to the family Rosaceae, and its fruit is widely used in the food industry, in processing, and in the preparation of juice, preserves, jam and other products. Quince fruit is significant because its composition contains pectin substances, organic acids, vitamins and mineral compounds [1].

Growing quince under the soil and climatic conditions of Uzbekistan is considered one of the important directions of horticulture. However, during the vegetation period of the tree, yield and product quality may decrease under the influence of various fungal and bacterial diseases and pests [2].

One of the important diseases occurring on the quince tree is leaf spot, the main causal agent of which is Diplocarpon mespili. The disease forms reddish-brown or dark-colored spots on the leaves. Under conditions of severe damage, the leaves turn yellow and fall prematurely. In some cases, spots and deformations are also observed on the fruits [3].

Fire blight (Erwinia amylovora) is considered one of the dangerous diseases for quince. The disease damages flowers, shoots and fruits, and causes young shoots to dry out and bend over [4].

In addition, fruit rot diseases, powdery mildew and other phytopathological problems may also have a negative effect on the phytosanitary condition of the quince tree [5].

Among pests, codling moth (Cydia pomonella), various aphids (Aphididae), scale insects (Coccoidea), leaf-rolling insects (Tortricidae) and other phytophages damage the vegetative and generative organs of the quince tree [6].

Under traditional conditions, the detection of diseases and pests is based on visual observation and the experience of specialists. In large orchard areas, this process may require a great deal of time. Therefore, the development of digital diagnostics and automated monitoring systems is of important scientific and practical significance [7].

In recent years, the development of artificial intelligence, machine learning and computer vision technologies has been expanding the possibilities of detecting plant diseases on the basis of digital images [8].

The aim of the research is to create the scientific and methodological foundations of an electronic software system that makes it possible to detect diseases and pests occurring on the quince fruit tree on the basis of digital images, to assess the degree of damage, and to develop recommendations on protection measures.

The main objectives of the research: to identify the main species of diseases and pests occurring on the quince tree; to form a digital image database of healthy and damaged leaves, shoots, flowers and fruits; to develop algorithms for classifying diseases and pests on the basis of images; to determine the area of damaged organs and the degree of damage; to form an automated diagnostic model based on artificial intelligence; to provide recommendations on protection measures through the electronic software; to evaluate the effectiveness of the software product under field and laboratory conditions.

Materials and Methods

The diseases and pests occurring on the quince (Cydonia oblonga Mill.) tree 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 and classifying quince 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:

1. **Field observation method.** Observing the signs of diseases and pests occurring on the leaves, shoots, flowers and fruits of trees in quince orchards.
2. **Digital photography method.** Photographing healthy and damaged plant organs using a mobile phone or a digital camera.
3. **Image processing method.** Standardizing the size, brightness, contrast and color parameters of images.
4. **Machine learning method.** Creating a model for the automatic classification of diseases and pests on the basis of the collected images.
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 a digital database of quince diseases

For the electronic software to operate effectively, it is required to create a classified database of the main diseases occurring on the quince tree.

Table 1. Main diseases occurring on the quince tree and their digital diagnostic signs

№	Disease name	Causal agent	Main signs in the digital image
1	Leaf spot	Diplocarpon mespili	Reddish-brown spots with dark borders on leaves
2	Fire blight	Erwinia amylovora	Drying of flowers, blackening and bending of shoots
3	Fruit rot	Monilinia spp.	Brown rotten parts and mold on the fruit
4	Powdery mildew	Podosphaera spp.	White powdery coating on the leaf surface
5	Rust	Gymnosporangium spp.	Orange-yellow spots on leaves and fruits
6	Root collar rot	Various soil pathogens	Blackening and rotting at the root collar and weakening of the tree

In the digital detection of diseases, in addition to their specific external signs, it is advisable to take into account the stage of disease development, weather conditions and the physiological state of the tree.

Digital database of quince pests

Table 2. Main pests of the quince tree and the signs for their digital detection

№	Pest name	Scientific name	Main signs in the digital image
1	Codling moth	Cydia pomonella	Larval entry hole in the fruit, internal gnawing and frass
2	Apple aphid	Aphis pomi	Leaf curling, accumulation of insects on young shoots
3	Green peach aphid	Myzus persicae	Small aphid colonies on leaves and young shoots
4	San Jose scale	Quadraspidiotus perniciosus	Small shield-like coverings on fruits, shoots and branches
5	Leaf-rolling insects	Tortricidae	Rolling of leaves and traces of feeding by larvae
6	Spider mite	Tetranychus urticae	Small whitish dots and fine webbing on the leaf surface

These pests are included in the database as phytophages that may occur in quince orchards. Their regional distribution and economic significance must be confirmed through local field observations.

Results and Discussion

Mechanism for detecting quince diseases by means of electronic software

The proposed electronic software is intended to receive and process digital images taken from various organs of the quince tree and to identify the type of disease or pest [9].

It is proposed that the software operate in the following algorithmic sequence.

Stage 1. Uploading the digital image.

The user photographs the leaf, shoot, flower or fruit of the quince tree with a mobile phone and uploads it to the electronic software.

The following information is entered together with the image: quince cultivar; tree age; region where the orchard is located; vegetation stage; observation date; type of plant organ.

Stage 2. Image processing.

The quality of the uploaded image is checked. Brightness, contrast and image size are standardized. Areas affected by disease are separated by means of a segmentation algorithm [10].

Stage 3. Diagnostics by means of artificial intelligence.

The image is passed to a pre-trained neural network model. The model analyzes the color, shape, texture and other visual features characteristic of a disease or pest [13].

Stage 4. Determining the degree of damage.

The degree of damage of quince leaves by disease is determined by the following formula:

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

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 quince leaf is 75 cm^2 and the damaged part is 15 cm^2:

$Z = (15 / 75) \times 100 = 20\%$.

Thus, 20 percent of the leaf surface is damaged by disease signs [11].

Stage 5. Forming the diagnostic result.

The software presents the following information to the user:

- the name of the probable disease or pest;
- the reliability indicator of the diagnosis;
- the area of the damaged zone;
- the degree of damage;
- recommendations on the next inspection and protection measures.

Stage 6. Electronic monitoring.

The diagnostic results are stored in the electronic database. This makes it possible to observe the dynamics of the spread of diseases and pests in quince orchards.

Functional modules of the electronic software product

Table 3. Main modules of the software for digital analysis of quince diseases and pests

№	Software module	Main function
1	User module	Login to the system and registration
2	Orchard data	Data on orchard area, cultivar and tree age
3	Disease database	Disease types and diagnostic signs
4	Pest database	Pests and their damage signs
5	Digital diagnostics	Automatic detection by image
6	Damage analysis	Calculation of the damaged area and percentage indicator
7	Protection recommendations	Preventive and control measures
8	Monitoring	Observation results by time and region
9	Report	Forming electronic reports

Mathematical assessment of diagnostic results

In determining the effectiveness of the electronic software, it is recommended to use the following statistical indicators of the classification model [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 – cases in which a disease or pest was correctly detected;

TN – cases in which a healthy object was correctly identified;

FP – cases in which a healthy object was incorrectly assessed as damaged;

FN – cases in which a damaged object was assessed as healthy.

Calculating these indicators separately for each type of disease and pest makes it possible to correctly assess the reliability of the software model.

Determining protection measures by means of the electronic software

One of the important functions of the software product is to form appropriate protection 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
Leaf spot	Collecting and destroying fallen leaves, thinning the tree crown
Fire blight	Sanitary pruning of diseased shoots, disinfection of pruning tools
Fruit rot	Destroying damaged and mummified fruits, preventing fruit injury
Powdery mildew	Pruning damaged shoots, improving air exchange inside the crown
Codling moth	Pheromone traps, monitoring of fruits, destroying damaged fruits
Aphids	Protecting beneficial entomophages, monitoring the degree of damage
Scale insects	Monitoring damaged shoots, sanitary measures and, where necessary, use of permitted preparations
Spider mite	Biological control, regular monitoring and, where necessary, use of selective acaricides

Recommendations on the use of chemical protection agents must be based on the preparations permitted for use on the quince crop, the current norms, waiting periods and safety requirements.

For dangerous diseases such as fire blight, the software should not give a final diagnosis on the basis of a photograph alone, but should recommend laboratory testing and the conclusion of a specialist [14].

Prospects for introducing the electronic software into practice

The proposed software product can be used in farms growing quince, horticultural agroclusters, scientific research institutions and plant protection organizations.

The use of the software creates the following opportunities:

1. Detecting quince diseases at an early stage.
2. Regular monitoring of the spread of pests.
3. Quantitative assessment of the degree of damage of leaves and fruits.
4. Forming an electronic phytosanitary database by orchard.
5. Providing rapid diagnostic information to agronomists and farmers.
6. Timely planning of protection measures.
7. Creating geographic maps of the spread of diseases and pests.

The software may initially be developed in the form of a mobile application or web platform, and later integrated with GPS and geographic information systems.

In training the model, 70 percent of the images can be allocated for training, 15 percent for validation and 15 percent for independent testing. In this case, it is necessary to prevent similar photographs taken from one tree from being mixed into different groups. The final testing should also be carried out on the basis of images taken in other orchards and in other vegetation periods [15].

Conclusion

Creating electronic software for the digital analysis of diseases and pests of the quince (Cydonia oblonga Mill.) fruit tree is considered one of the promising directions for improving phytosanitary monitoring in horticulture and introducing modern information technologies into practice.

The following scientific and practical conclusions were formed on the basis of the research: There are possibilities of detecting diseases occurring on the quince tree, such as leaf spot, fire blight, fruit rot and powdery mildew, on the basis of digital images. The creation of a special digital image database is required for the automatic detection of codling moth, aphids, scale insects and other pests. The use of artificial intelligence and computer vision algorithms serves to automate the process of initial detection of diseases and pests. By means of digital images, it is possible to determine the degree of damage of quince leaves and fruits as a percentage and to monitor the dynamics of disease development. In assessing the effectiveness of the electronic software, it is important to compare the diagnostic results with the conclusions of phytopathologist and entomologist specialists. By introducing the software product into quince orchards, the possibilities of improving phytosanitary monitoring and organizing measures to combat diseases and pests in a timely manner are expanded.

In general, creating electronic software for the digital analysis of diseases and pests of the quince fruit tree serves the application of digital technologies in horticulture, plant protection, and the making of scientifically grounded decisions in production.

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