APPLICATION OF GIS AND REMOTE MONITORING TECHNOLOGIES IN THE STUDY OF THE BIOECOLOGY OF TOMATO PESTS (ON THE EXAMPLE OF ANDIJAN REGION)

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Abstract: The article provides an in-depth analysis of the bioecological characteristics, life cycles, and distribution factors of the main pests of tomato crops - Tuta absoluta, aphids, and thrips - in the conditions of the Andijan region. In particular, the possibilities of using modern GIS (Geographic Information Systems) and remote sensing technologies (drones, multispectral cameras, satellite images) for the timely detection of these harmful organisms and planning effective measures to combat them are highlighted. Also, in pest monitoring, forecasting models based on AI (artificial intelligence), Random Forest, YOLO, NDVI indices, and early warning systems are explained with practical examples. The article, based on the real conditions of the Andijan region, reveals ways to implement innovative approaches in tomato agroecosystems.

Keywords: Tomato pests, Tuta absoluta, GIS technologies, Remote sensing, drone monitoring, NDVI index, Satellite imaging, Artificial intelligence (AI), Random Forest, YOLO, Andijan region, Bioecology, Early warning system, Feromon traps, Tomato agroecosystem

Introduction. Tomato (Solanum lycopersicum) is one of the most important vegetable crops in the world, and its product plays an important role in human nutrition. However, tomato cultivation is seriously threatened by various pests - on a global scale, it is noted that insect pests damage an average of 13-14% of the yield of agricultural crops. In regions with a warm climate, such as the Andijan region, the most harmful pests to tomato crops are the tomato moth (Tuta absoluta), various aphids, and thrips. It is known that in the conditions of the Fergana Valley (including Andijan), the tomato moth has become one of the five most dangerous pests of vegetable and melon crops in recent years. In this article, using the example of the Andijan region, the bioecological characteristics of tomato pests and the use of modern geoinformation systems (GIS) and remote sensing technologies (drones, satellite imagery, etc.) in monitoring their distribution are analyzed. Attention will also be paid to the implementation of artificial intelligence (AI) and algorithms in the

observation process, increasing the effectiveness of monitoring, and forming early warning systems.

Main tomato pests and their bioecology

In the Andijan region, among the main insects damaging tomato yields in open fields and greenhouses are the Tuta absoluta (tomato moth), aphids, and thrips. Below, these pests and their bioecological characteristics (life cycle, reproduction and distribution factors) are described.

Tuta absoluta (tomato moth)

The tomato moth is a small moth (butterfly) that originated in South America and has rapidly spread throughout Europe, the Middle East, Asia, and Africa since 2006. In Uzbekistan, this invasive pest was first identified in 2016 and is currently found in many tomato-growing regions of the country. Tuta absoluta is an oligophagous plant, mainly characteristic of tomatoes, and can also damage other nightshade crops (potatoes, eggplants, tobacco, etc.). Its eggs are small (0.35 mm) and are laid one by one on the leaf surface; each female butterfly can lay up to 250-300 eggs during its lifetime. The hatched larvae feed by forming shafts inside leaves and fruits - this shaft-like damage is a characteristic feature of tomato moths, manifesting as large wounds in leaves and small holes in fruits. The larva develops in four stages, completing development in 13-15 days; then pupates in the soil or in plant debris. Adults (imago) are small grayish-brown butterflies, with a body length of only ~6 mm, narrow wings, and black spots on top. The life cycle is very short - under optimal conditions (25-27°C), it takes only 30-35 days for the egg to hatch and reproduce. Therefore, in warm regions, this pest can develop up to 10-12 generations throughout the year (even in greenhouse conditions). For example, in observations conducted in the central part of the Fergana Valley, it was noted that Tuta absoluta produces 5-6 generations during the season (even 6 generations, including those in the warehouse), the development period of each generation lasted about a month. Reproduction conditions are very suitable for sunny and warm climates, and larval development accelerates when the daily temperature is around 25-30°C. In this case, the pest continues to multiply in the open field until the end of autumn; with the arrival of winter, it can partially survive in the pupal or adult moth stage. Studies have shown that in the Fergana Valley, the tomato moth can overwinter in the egg, pupa, and adult moth stages. In particular, in the Andijan region and adjacent territories, larvae and pupae are found in open areas before the onset of autumn cold, and in winter, the adult stage of the live moth is observed in greenhouses (for example, in the Tashlak

district). This pest flies actively during hot days (mainly at night) and can spread itself over short distances, but the factors of its spread are mainly related to human activity: it quickly penetrates new territories through the sale of infected tomato seedlings or fruits, packaging material, and other products. The influence of absolute mustard on local crops can be extremely destructive - if effective control measures are not taken, it is noted in scientific sources that it can potentially destroy 80-100% of tomato yield. For example, in the conditions of Uzbekistan, during the first invasion in 2016, it was observed that the tomato moth spread to almost 100% of the field in some farms within a few weeks (on the example of the Zangiata district of the Tashkent region). Therefore, the tomato moth is currently recognized as a pest that poses a serious threat to the agricultural sector of the region and requires early detection and control.

Aphids (plant lice):

Among the juicy pests that pose a threat to tomato plants, the most common are the green peach aphid (Myzus persicae) and related species, which form colonies on tomatoes and other vegetables and feed by sucking plant sap. Insects are very small, soft-bodied insects (1-2 mm long), often living in clusters on the underside of leaves or at the tips of branches. Their color can be greenish-yellow, sometimes pink, dark. aphids have a specific life cycle: female individuals often reproduce directly by live birth without males (through parthenogenesis). This allows them to grow populations very quickly - at the optimal temperature (around 25 °C), the full development of one generation is completed in only 10-12 days. In regions with a warm climate (for example, in the spring-summer months of the Andijan region), aphids are capable of producing 20 or more generations per season. Each female aphid can produce an average of 30-80 offspring, and its lifespan is limited to several weeks. As the aphid colony becomes dense, winged morphs appear in the population, which migrate to new plants and expand the colony. Breeding conditions: mild and warm weather is most favorable for aphids' reproduction; their offspring grow quickly in high humidity and moderate temperature. Several generations alternate before autumn, and at the end of autumn, when the days become shorter, some species develop sexual females and males, laying overwintering eggs (often fruit trees - for example, peaches, apricots of the Prunus genus). Distribution factors: aphids affect many plant species and are found almost everywhere; due to their small size, they can be spread over long distances by wind. Especially when seedlings infected with aphids that have multiplied in greenhouses or nurseries are brought to the field, the pest quickly spreads to new areas. Indeed, aphids that

live in the greenhouse year-round and spend the cold season move to open fields and household plots with seedlings in spring. While aphids damage tomatoes directly by inhibiting nutrient competition and assimilation, the sweet "aphid" liquid they secrete leads to the appearance of fungal moths (soy spots) on the leaves. Most importantly, aphids spread dangerous viral diseases through their sucking mouthparts - for example, pathogens such as tomato mosaic virus and potato virus Y common in tomatoes migrate specifically through aphids. Therefore, early control of aphids plays an important role in preventing viral diseases.

Thrips:

Trips (belonging to the order Thysanoptera) are also dangerous pests of tomatoes and other heat-loving crops. The most common species in the Andijan region is the Western Flower Thrips (Frankliniella occidentalis), as well as the Tobacco Thrips (Thrips tabaci). Trips are very small, thin-bodied insects, about 1 mm long, usually yellowish-brown in color, with narrow wings (perpetually flapping). Life cycle: stages of thrips development - egg, 2 larval stages, then immobile prepupa and pupa stages, then imago (adult) stage. In hot conditions, the complete cycle can be completed very quickly - within 7-15 days. For example, if the optimal temperature range is around 20-35°C, a week will be enough for the egg to hatch. Therefore, during the summer months, thrips reproduce by merging several generations, and the population can increase dramatically. Female thrips lay eggs on leaf or flower tissue; larvae feed under the leaf or on the petals. The larval stages are very mobile and feed by sucking plant cell sap, resulting in the appearance of small whitish-dirty (silver-like) spots on the leaves. Affected leaves dry and wrinkle, and flowers and fruits may fall off. Breeding conditions: dry and hot weather contributes to the spread of thrips - if relative humidity is low, they multiply quickly, otherwise, heavy rains can wash them away and reduce the population. Usually, thrips survive the winter in a greenhouse or in the soil in the form of a surviving adult female, as it is difficult to survive in an open field in a cold climate. Distribution factors: although thrips cannot fly actively, they can move passively over considerable distances in the wind due to their light body. Also, the transfer of infected seedlings and products to new locations is a source of spread. These pests cause double damage to tomato plants during the feeding process: firstly, they damage tissues and slow down growth; secondly, they are very dangerous - they transmit viral diseases. In particular, the tomato bronze spot virus (TSWV - Tomato Spotted Wilt Virus) is spread by thrips and causes great damage to

tomato growers. This virus is only taken from the plant by thrips larvae, then persists in the imago thrips body throughout its life and continues to infect other plants. As a result, even if there are several infecting thrips in the field, they can quickly spread the virus throughout the field and destroy a significant portion of the harvest. The virus-carrying nature of thrips makes them especially dangerous pests and requires early warning and entomological control measures against them.

Pest distribution mapping using GIS technologies:

Modern Geographic Information Systems (GIS) serve as a powerful tool for monitoring and analyzing the distribution of pests in agricultural entomology. With the help of GIS, it is possible to conduct spatial analysis of data collected from sites, to accurately map the areas where the pest is distributed, and to identify risk zones. In the Andijan region, the use of GIS technologies for pest monitoring in horticulture and vegetable growing has also begun. For example, if field inspection data is collected together with coordinates through special GPS devices or mobile applications and entered into ArcGIS or QGIS programs, the points where the pest was encountered are displayed on the map. With the help of this approach, it is possible to determine in which districts and farms the damage was observed in a short period of time, and to create maps of regional distribution. With the help of such maps, it is possible to visually analyze the spatial concentration, directions of distribution, and dynamics of tomato pests.

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