Value of mathematical modeling for genetically modified crops

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Abstract: Despite the high-tech innovation level of cultivation and processing, damage by insects - pests, is still high. In this connection, a sense of urgency growing new genetically modified (GM) varieties agricultures containing the gene of the soil bacterium called transgenic or genetically modified. This article explains the importance of mathematical modeling for the cultivation of GM crops.
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Introduction

Genetically modified plants are involved in agricultural use, are of great practical importance and scientific interest, because in conjunction with the pests act as antagonistic communities, lead to the formation of spatially inhomogeneous, including self-organizing, structures. Spatial heterogeneity of population distribution is one of the most intensively studied areas of theoretical biology. This phenomenon is widely spread in the nature; actually, it would be difficult to imagine an ecological system homogeneously distributed in space [1]. Spatial heterogeneity is observed in different biotopes [2] and can be caused by various reasons [3]. Development of new mathematical modeling techniques to solve the problem of predicting the dynamics of populations of genetically modified, including a set of interrelated models, their numerical implementation in the form of software packages based on the direction of movement of the population, the retardation effects and types of interaction is an urgent problem in the field of mathematical modeling of complex systems and is of interest to a large area of research. Currently, methods inspired by natural systems are widely applied virtually in all areas of science and technology [4]. Mathematical modeling has an important role in studies of transgenic biotechnology, allow you to build models of complex agro-ecological systems, and to investigate their dynamic properties.

Description of the problem

Applied problem of using transgenic agricultures to suppress the population of insect pests in the fields is the need to reduce the risk of pest adaptation to Bt-toxin produced by transgenic crops, given the constraints on the spatial configuration of the system and given a scenario, the strategy of "high-dose refuge" recommended to monitor the development of resistance of the pest to Bt-plants. "High-dose" means that the level of toxicity of Bt-plants is high enough to kill nearly all larval. A small percentage of survivors (Bt-resistant) individuals should be suppressed by the emission of transgenic fields or near special areas not modified plants (shelters), are the source of Bt-susceptible individuals that mating with Bt-resistant, should reduce the percentage of the last offspring.

One of the important problems of constructing models of spatio-temporal dynamics of pests of agriculture under the influence of the transgene is the lack of experimental values, taking into account the local conditions of climate, soil and biological characteristics of the pest, etc. For example, the structural features of the wings of meadow and stalk corn borer do not allow them to move freely in space as the rest of the "flying" insects. In particular, they cannot perform long flights and rarely rise high enough off the ground. As a result, the upper ears are least exposed to the action of pests. However, this is not their only feature. Part pests heat transfer over the air, which in turn affects the formation of the diffusion fluxes. In a whole range of problems [5], it is believed that propagation takes place not all over the space but on the region's border or particular surfaces inside it. This leads to the propagation of the wave mainly along those borders or, in any case, the propagation of the wave throughout is defined by surface phenomena. An analogous situation occurs in the ocean, where the propagation of a whole range of species occurs only in the near-surface layer [6, 7].

None of the directions of classical biological control of pests has been as efficient in large territories as introduction of phytophagous insects from the native ranges of adventive plants (Hoffmann, 1995; Julien and Griffiths, 1998; Myers

and Bazely, 2003; Page and Lacey, 2006; van Klinken and Raghu, 2006). Although this direction is 150 years old (Müller-Schärer and Schäffner, 2008), it still lacks a systemic approach, either to determining the factors of efficiency of biological control or to finding the most efficient agents. Success in biological control may be considered in terms of a lottery model (Myers, 1985) with unpredictable results [8]. The existing mathematical methods of modeling and simulation system does not take into account the effectiveness of the "safe havens", depending on their form and distribution in the space, the diffusion coefficient is estimated that casts doubt on the sustainability and effectiveness of long-term predictions of such models. As a result, there are many questions that require further study the behavior of pests. Ecological and demographic processes as well as evolution transformations in population undergoing spatially heterogeneous wave regime differ from what might be expected for homogeneously well-mixed case of population dynamics [9].

The reason for the ineffectiveness of modern mathematical modeling, simulation systems and analytical methods for studying them is that they do not allow you to monitor changes in the dynamics of other types of pests that with the decrease of the competing species spread more and more, such as the white-winged bug or cotton worm to stalk corn borer [10]. The larvae of both species of pests feed on all above-ground parts of the plant, but a modified corn destroys only the offspring of the latter.

Attempts to genetically engineered transgenic lines agricultures, resistance to pests, so far not yielded the expected results. T. Wilson and J. Tollefson of the University of Iowa (USA) conducted a test of transgenic maize lines producing crystals toxin Cry 3 Bt, normally produced by the bacterium *Bacillus thuringiensis var. tenebrionis*. Although some species and had an increased resistance to the western corn beetle, the degree of resistance was not high enough. The reason for this is that the toxins produced in the chloroplasts, whereas the larvae feed on the roots of plants, where virtually no chloroplast. As a result, a significant portion of the larvae feeding on the roots of agriculture transgenic lines survived. Imago derived from such larvae, a number of indicators (the ability to fly, fertility, longevity and size) were like adults, received the "regular" plant. Solving these problems is seen in the development of effective models and methods of pest adaptation to changes in prey, in particular, to transgenic varieties agricultures based on genotype pests, as well as depending on the type of their activities - foraging or reproduction.

This issue in Russia and abroad engaged researchers such as Kostitsyn VA, Svirezhev YM, Pasekov VP, Altukhov YP Tyutyunov YV, Zhadanovsky EA, Arditi R ., Abrahamson D., Wilensky U., Bourguet D., Chaufaux J., Séguin M., Buisson C., Hinton J.L., Stodola T.J., Porter P., Cronholm G., Buschman L.L., Andow D.A., Onstad D.W., Guse C.A., Spencer J.L., Peck S.L., other. In the works of foreign authors dominated simulation; significant contribution directly to the mathematical modeling of the dynamics of modified crops made by Russian scientists, including scientific school Tyutyunov Y.

However, despite the significant number of publications, many of the effects that are essential for improving the accuracy and reliability of long-term forecasts related to the spatial inhomogeneity of the medium, with the interspecific competition, taxis, retardation effects and adaptation of plant resources, remained unaccounted for in the mathematical models.

Conclusion

The heterogeneity of the distribution of biomass within a population, both in imitation models and demo-genetic models, is explained by the occurrence of diffusional instability as a result of inhomogeneous concentration, which can serve as the beginning of formation of dissipative structures. Varied concentration of plants on the field can depend on the following factors: lag processes, which are typical of annual crops and are behind the uneven growth and development of plants, as well as patchiness, which occurs due to different sizes of transgenic and regular crop species and competition between them [11]. The development of effective mathematical modeling, simulation systems and analytical methods for studying them and obtaining sufficiently accurate forecasts concentration pests, would help reduce the cost of the crop.

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