New Factors of Efficiency of Phytophages: A Solitary Population Wave and Succession Process

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Abstract

In a study of acclimatization of Zygogramma suturalis, introduced from North America to the USSR for biological control of ragweed, a new biological phenomenon has been found: an insect constant wave having a stable velocity and shape. This wave process is called a solitary population wave (SPW), and is described by a new mathematical model. The SPW is characterized by maximum efficiency, and the weed is destroyed completely in a short period. The SPW holds an intermediate position between autowaves and solitons. As a result of the rapid exponential growth of phytophage numbers in a vacant ecological niche of an adventive weed, a regular SPW is formed. This is a circular wave 1.5 km long and about 10 m wide, consisting of about 10 million beetles. Movement of the SPW resembles propagation of a steppe fire; i.e., an autowave of burning. Geobotanical studies and computer factor analysis have revealed a strong SPW impact on the direction and rate of the succession process. Similar waves must have occurred in North America and Australia during introduction of phytophages in the nidi of adventive weeds.

Introduction

Zygogramma suturalis F. (Coleoptera: Chrysomelidae) was introduced from North America to the southern USSR for biological control of the quarantine weeds Ambrosia artemisiifolia L. and A. psilostachya DC. (Asteraceae) (Kovalev 1981, Kovalev and Medvedev 1983). During evaluation of effects of Z. suturalis, a new biological phenomenon was found: an insect constant wave having a stable velocity and shape. This wave process, described by a new mathematical model, is called a solitary population wave (SPW) (Kovalev and Vecherin 1986).

In an area where the SPW is observed, every A. artemisiifolia plant is destroyed. The new class of wave processes in populations has added to the conventional concepts of efficiency of introduced biological control agents (Harris 1973), and may reveal new possibilities for biological control.

In the past two decades a new trend in physics of non-linear processes has been discovered, which is known as solitons. In this process, solitary waves consist of solitons and autowaves, and are commonly represented by bunches of particles moving with a constant velocity and preserving their shape.

In recent years there have been many attempts to substantiate mathematically the phenomenon of solitary waves in populations (Ivanov 1984). However, these have been purely theoretical studies, and none describe solitary waves for introduced biological control agents.

According to the new model, the SPW holds an intermediate position between autowaves and solitons, and possesses characteristics of both (Kovalev and Vecherin 1986, 1986a). Like the autowave the SPW brings about an irreversible change of the environment where it moves; i.e., complete destruction of the weed.

For the insect SPW to be formed the insects should have in the initial distribution area a certain critical density allowing for providing the necessary number of insects per unit of the wave front width (up to 5000 beetles per metre).
A population with a high density forming a moving zone is different from normal aggregations in the period of outbreaks in populations. We have observed the SPW in introduced phytophagous species. As a result of the rapid exponential growth of phytophage numbers in the vacant ecological niche of an adventive weed, at a maximum density of the phytophage, a regular SPW is formed which is called a "self-organizing SPW".

Unfortunately a SPW cannot be determined without applying a special counting technique. However it can be easily found in photographs. For example, in Huggle (1957), a photograph of a typical SPW consisting of thousands of St. John's wort (Hypericum perforatum L.; Clusiaceae) beetles Chrysomela quadrigemina (Suffrian) (Coleoptera: Chrysomelidae) in California is included, although no comments are given. Also, in Room (1986), the structure of a SPW of Cyrtobagous salviniae Calder and Sands (Coleoptera: Curculionidae) on salvinia (Salvinia molesta D.S. Mitchell; Salviniaeae) can be seen in the photographs and in the diagrams. The SPW is characterized by maximum efficiency: the weed is destroyed completely in a short period.

Method and Materials

The main counts for describing the SPW of Z. suturalis were carried out in the Stavropol region in crops infested with A. artenisiifolia. The counts were made along stationary and non-stationary transects. Length of the transects was about 100 m of the Z. suturalis wave front. Samples were taken from every transect from a site of 0.1 m, where the numbers of specimens, larvae and eggs of Z. suturalis were counted, percent of the damage caused was calculated, and phytoass of ragweed and crops was determined. Nine hundred sample sites were studied in 1985. The SPW impact on the succesion process was studied on uncultivated areas of 18 ha (Kovalev et al. 1986).

Results and Discussion

Movement of the Z. suturalis SPW resembles propagation of a steppe fire; i.e., an autowave of burning. We have observed a circular wave 1.5 km long and about 10 m wide consisting of about 10 million of beetles moving across a field of esparcet. The wave shape and velocity (up to 3 m/day) remain constant. Formation of the SPW in crops of different cultures (alfalfa, esparcet, maize and wheat) was accompanied by an increase of their yield. It follows from the mathematical model (Kovalev and Vecherin 1986) that, for the SPW moving with a certain velocity V to be formed, a definite density of insects per unit of the width of the wave front is needed,

\[ n = p_o V/A, \]

where \( p_o \) is density of ragweed destroyed by the wave, \( A \) is quantity of ragweed consumed by one individual per day. For example if \( p_o = 250 \) g/m, \( A = 0.024 \) g/day, and \( V = 0.5 \) m/day, 5,300 beetles/m of the wave front is necessary for the SPW formation. This density was attained by the seventh generation after introduction.

Opposed to such high population densities are normally different mechanisms regulating ovipositional selectivity. However, when a SPW is formed, there is a delay in the action of this mechanism (Resnik 1988).

An outbreak of insects was responsible for appearance of flying individuals in the period of acclimatization of Z. suturalis (Kovalev 1986). The individuals introduced from Canada and USA are unable to fly, which has been quite recently substantiated by study of auxillary structure (A. Brodsky, personal communication).

In the first years of acclimatization it, was found for the first time that an introduced phytophage plays an important role in the succesion process (Kovalev 1986). Geobotanical studies and computer factor analysis have revealed a strong SPW impact on the direction and rate of the succesion process. Owing to the SPW impact, the first and second succesion stages have the same periodicity as those in phytocenoses of North America. The SPW in a
ragweed nidus is induced by an outbreak of *Erigeron canadensis* L. (Asteraceae) abundance. This species is normally predominant at a first succession stage in North America.

References


