

Bio-Efficiency of Acetamiprid and Its Application Technology against Aphids on Potato Plants

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Abstract

The article presents the results of a study on the bioefficacy of acetamiprid, an insecticide from the neonicotinoid class, in the form of a suspension concentrate, containing 180 and 560 g/L; a water-soluble concentrate containing 180 g/L; water-dispersible granules containing 700 g/l of the active ingredient; and an aqueous solution of 0.1 g/L for the protection of seed potatoes from potato aphids, which carry viruses aphids have tended to be more prevalent than others on potatoes in Russian Federation and throughout the world, aphid is one of most dangerous and important pest of potatoes this pest damage directly such as stunting the plant growth and reducing yields via sap-sucking, and developing sooty mold on its honeydew and undirect damages, like transmission of potato viruses. The following insecticide application technologies were used: pre-planting treatment of tubers, treatment of the furrow bottom simultaneously with planting tubers, and spraying of plants. A conclusion was made about the high biological efficiency of insecticide Acetamiprid up to 100%, as well as the possibility of effective use of various technologies for applying the insecticide against aphids on seed potatoes both in open and protected ground in the Moscow region.

Keywords

Biological Efficacy, Potato Aphids, Viruses, Applications, Plants

1. Introduction

Potato is one of the most important staple foods globally and is also valued for its high nutritional content and ingredients. This plant originates from the Andes

region of South America. These crops have become a crucial component of diets worldwide due to their rich content of carbohydrate, essential vitamins like vitamin C, B-complex vitamins, some minerals potassium, magnesium), and dietary fiber [1]. In addition to their nutritional value, potatoes are valued for their ability to grow in diverse climates and soil conditions almost in all parts of the globe, making them accessible and economically significant in both developed and developing countries [2]. The global production of potatoes has routinely increased over the past years, reflecting its importance as a staple food. According to the Food and Agriculture Organization (FAO), global potato production reached approximately 470 million metric tons in 2022, with major producers including China, India, Russia, and Ukraine [3].

Viral and viroid diseases significantly reduce the efficiency of potato growing [4]. Viral epiphytotics occur in years when a large number of aphid vectors appear, when viruses spread especially rapidly, which negatively affects the economics of potato seed production. The majority of aphidophilic potato viruses are non-persistent viruses that are transmitted over a relatively short distance during a very short period of vector feeding on diseased and healthy plants. Since the overwhelming majority of these viruses are widespread in the main potato-growing zones, the development of measures to protect seed crops from their vectors is an urgent need, and in this case the main role belongs to the chemical method [5].

The following aphid species are of greatest economic significance as virus vectors in potato crops: *Myzodes persicae* Sulz., *Aphis nasturtii* Kalt., *Aphis frangulae* Kalt., *Macrosiphum euphorbiae* Thom., *Aulacorthum solani* Kalt. [6]. The number of aphid species registered worldwide as virus vectors increases annually, and some researchers [7] believe that any aphid species can be considered a vector of viral infection. It has been established that the period of possible colonization of potato fields by both different aphid species and their complex can last up to 9 weeks or more [8].

Optimally, during this entire period, it is necessary to ensure the death of migrant aphids in seed crops during their first attempts to feed on the protected plant, since the period from potato germination to flowering is characterized by high sensitivity to viruses. Pests often feed inside folded leaves and in the lower part of the potato bush, which hinders the active work of contact-acting preparations. Therefore, the main requirements for preparations in this case are high efficiency and duration of their aphidic action, in order to minimize the frequency of treatments. For the same reason, the most rational way to protect potato seed crops is to use systemic insecticides [9].

A new interstate standard “Seed Potatoes. Specifications and Methods for Determining Quality” was introduced into the potato seed certification system in the Russian Federation [10]. According to GOST, seed potatoes are not allowed to contain pathogens of infectious diseases and pests of quarantine significance (potato cancer, brown bacterial rot, golden cyst nematode, potato moth, etc.); differentiated standards have been established for the control of phytopathogenic vi-

ruses based on laboratory testing of leaf and tuber samples depending on the stage of propagation of the original seed material, including the original in vitro material, minitubers, the first field generation from minitubers, and the super-supere-lite [11].

For all classes (generations) classified as original seed material, fairly strict regulatory tolerances have been introduced for viruses that cause severe forms of rugose and streak mosaic (RSM), potato leaf curl (PLC), and spindle tuber viroid (SPTV) [12]. The presence of RSM and SPTV in the original in vitro material and minitubers is not permitted. In the first field generation of minitubers, the maximum permissible level should not exceed 0.5%, and in the super-super-elite, 1%. A zero tolerance has been established for SPTV for all generations [13].

Control of potato viral diseases must be carried out at all stages of potato seed production: in the laboratory, in protected soil, and in the field [11]. For a long time, minituber cultivation was focused on heated winter ground greenhouses. Today, producers are using less expensive technologies for growing minitubers in spring and summer rotations in unheated tunnel-type frame shelters using lightweight synthetic covering materials [14].

A set of agricultural practices limiting the spread of viral and other infections in field conditions [15] should include: ensuring the necessary isolation from other potato plantings of lower classes or commercial potato plantings, pre-planting treatment of tubers with insecticidal-fungicidal preparations, creating conditions most favorable for rapid growth and development of plants during the initial period of vegetation [16], monitoring the activity of aphid populations migrating in potato plantings, regular phyto-variety cleaning, the use of effective and environmentally safe plant protection products during the growing season, pre-harvest removal of tops by chemical or mechanical means when achieving optimal seed marketability of tubers, taking into account the dynamics of migrating virus carriers (flying generation of aphids) [17].

2. Materials and Methods

2.1. Location of Experiment and Weather Condition

Field experiments were conducted in the Moscow Region from 2023 to 2024 (Slavyanka-M LLC, Moscow Fruit and Vegetable Experimental Station, and experimental field of the Patrice Lumumba Peoples' Friendship University of Russia) on seed plots of *Solanum tuberosum* L. potatoes of the Nevsky, Udacha, Red Scarlet, and Charoit varieties. The test subjects were aphid adults and larvae of the family *Aphididae* (Figure 1).

Potato is a plant that grows in a cool temperate climate with average annual temperatures of 6°C to 10°C and relatively high humidity. The growth process begins when soil temperatures reach 8°C; temperatures above 30°C significantly slow development. At high temperatures around 25°C, tuber formation slows and ceases at 29°C to 30°C. At temperatures above 42°C, foliar growth ceases, as the plant expends more assimilatory products on respiration than the leaves accumu-

late through photosynthesis process. The growing season varies significantly depending on the variety and its maturity from 45 - 50 days for ultra-early varieties to 115 - 120 days for late varieties.

Sandy-loamy and light loamy soils are particularly suitable for growing potatoes. They remain loose throughout the growing season, do not become waterlogged after rain, have a slightly acidic pH, and contain at least 2% humus. Heavy soils require significant additions of organic fertilizers. The topsoil thickness for potato cultivation was at least 27 - 30 cm. Potato plants develop best and produce high-quality yields in well-aerated, loose soil that warms easily. With proper agricultural practices, the optimal pH was between 5.5 and 5.8 (slightly acidic soil). Potatoes are relatively sensitive to acidity and require liming only in moderately or strongly acidic soils.

According to data from the Russian Hydrometeorological Research Center, published by the Moscow State University (MSU, 2024). Meteorological Observatory was the hottest year ever recorded in Moscow region, the average annual temperature reached up to 8.2°C, with ten months of the year significantly warmer than normal, weather indicators for 2024 (based on Roshydromet reports): Hottest September: September 2024 was the hottest month ever recorded in Moscow, with an average temperature of 17.9°C, 5.7°C above the climate normal. The maximum temperature reached 33.1°C on July 4, with nine readings exceeding 30°C; the lowest point, -24.9°C (-12.8°F), was recorded on January 4, 2024.

The year of 2024 was a significant anomalies, including severe frosts from January 2 to 8, record snowfall in early January, and record-breaking warmth in April and the weather trends in 2024 was sunshine in September 2024, 263 hours of sunshine were recorded, Snow cover melted more than two weeks earlier than average, although January and May were colder than average, the rest of the year was consistently warmer, the Federal Hydrometeorological and Environmental Monitoring Service (Roshydromet, 2024).



Figure 1. The potato aphid on leaf of potato.

2.2. Methodology and Materials

Experimental variants: 1) Acetamiprid in the form of a suspension concentrate containing 180 and 560 g/l of the active substance; 2) water-soluble concentrate containing 180 g/l of the active substance; 3) water-dispersible granules containing 700 g/kg of the active substance; 4) a ready-to-use preparation in the form of

an aqueous solution containing 0.1 g/l of the active substance; 5) standard (registered preparation with a high protective effect used in practice); 6) untreated control. The placement of the plots was randomized, the plot size was 50 m², four replicates were used. The insecticide application method, depending on the formulation, included pre-planting tuber treatment, furrow bottom treatment, simultaneous with tuber planting, and plant spraying.

The biological efficacy of the product was measured by the reduction in aphid numbers relative to the control when applying treated tubers or furrow bottom treatment during tuber planting, and relative to the initial level, adjusted for control, when spraying plants. Field surveys included counting adults and larvae on 100 leaves, randomly picked from different plant layers in each replicate of the small-plot experiment. The timing of the surveys depended on the insecticide application method. When planting treated tubers or treating the furrow bottom during tuber planting: preliminary count (determining the time of aphid appearance in the control), 1st count—3 days after the appearance of aphids in the control, 2nd count—7 days after the appearance of aphids in the control, subsequent counts at 7-day intervals until desiccation (mowing) of the tops.

When spraying plants: preliminary count (immediately before treatment), 1st count—on the 3rd day after treatment, 2nd count—on the 7th day after treatment, 3rd count—on the 14th day after treatment, subsequent counts—as needed. to observe the appearance, population dynamics, and species composition of aphids growing minitubers in the greenhouses of the Patrice Lumumba Peoples' Friendship University of Russia (RUDN University) Educational and Experimental Garden, the yellow cup method (Merické's vessels) was used.

This method allows one to determine aphid flight activity and their species composition. The principle of the method is based on the ability of some aphid species to fly to the color yellow, as established by Merické. Vessels filled with water were placed between the experimental greenhouses, between the greenhouses and the forest belt, and inside the greenhouses where potato minitubers were grown. Two traps were placed directly in the greenhouses—at the beginning and end of the greenhouse. Insects were collected weekly in the morning at the same time. Insects from each trap were placed in vials with 70% alcohol. The entomological material caught in traps was identified in laboratory conditions (VIZR, senior researcher, PhD in Biology M.N. Berim).

3. Results and Discussion

The Promising insecticides against potato pests include modern products based on active ingredients from the neonicotinoid class. Representatives of this chemical class are characterized by high biological activity against a wide range of agricultural pests (including potatoes), relatively low application rates, strong systemic and translaminar activity in plants, and moderate persistence in the environment. One such product is Acetamiprid, which has contact, intestinal, and systemic action. Acetamiprid blocks postsynaptic nicotinic receptors in the nervous

system of harmful insects. As a result, signal transmission through the central nervous system of pests is suppressed, causing them to first lose motor activity, then stop feeding, and die.

Table 1. Acetamiprid formulations and its usages in different brand names.

No	Formulation	Description
1	Wettable powder	a solid formulation which is mixed with water before application.
2	Soluble powder	a common easy to mix formulation, often found as 20% soluble powder
3	Water-dispersible granules	granular form designed to disperse in water
4	Emulsifiable concentrate	a liquid formulation
5	Common brand names	this drug includes assail and Chipco and Katyayani k-Acepro

It should be noted that Acetamiprid poorly penetrates the mammalian blood-brain barrier and this insecticide is available in various formulations that include wettable powder, soluble granules, and soluble powders (**Table 1**). Consequently, neonicotinoids are highly toxic to pests and moderately or slightly toxic to mammals and control a wide range of pests especially sucking insects like aphids, thrips, and leafhoppers on various plants, including fruits and vegetable, the selectivity coefficient is >2000.

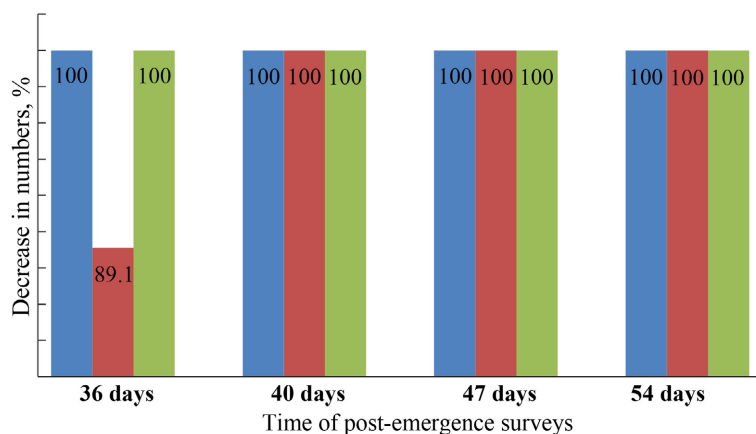
It has been established that the effectiveness and environmental safety of plant protection products can be significantly influenced by their application technology. The use of imidacloprid by treating the bottom of the furrow during potato tuber planting and by treating the tubers before planting minimized the product's exposure to air and subsequently to non-target organisms. The biological effectiveness of Acetamiprid, KS (180 g/L) in regulating aphid numbers during furrow bottom treatment during potato planting was assessed using the following scheme: imidacloprid, KS (180 g/L)—at application rates of 0.5, 0.75, and 1.0 l/ha, the standard—the preparation Aktara, WDG (300 g/kg)—at 0.6 kg/ha, a control without treatment.

The insecticide demonstrated high biological effectiveness (100%) in the variant with the maximum application rate of 1.0 l/ha throughout the entire survey period. Only on the 35th day after emergence did the biological effectiveness indicator reach 89.1% (**Figure 2**). The biological efficiency of Acetamiprid, KS (180 g/l) when used for treating tubers before planting was assessed using the following scheme: Acetamiprid, KS (180 g/l)—at application rates of 0.15, 0.2 and 0.25 l/t, the standard—the taboo preparation, VSK (500 g/l)—0.1 l/t and a control without treatment. The insecticide, with this application technology, showed high biological efficiency (100%) in the fight against aphids that carry viruses on potatoes over a practical period.

Only on the 40th day after emergence, in the variants with application rates of

0.15 and 0.2 l/t, the biological efficiency indicator was at the level of 86.1%, on the 47th day of surveys in the variant with the application rate of 0.2 l/t, this indicator was 70.0%. The use of Acetamiprid in the form of a water-soluble concentrate, also containing 180 g/l of insecticide, when applying furrow bottom treatment during tuber planting was carried out according to the following scheme: Acetamiprid (180 g/l) at application rates of 0.5 and 1.0 l/ha, the standard—the preparation Aktara (300 g/l)—0.6 kg/ha and a control without treatment.

Biological effectiveness, determined by the reduction in aphid numbers depending on the time after emergence, varied from 67.4% to 100% during the recording period for the 0.5 l/ha application rate, while at 1.0 l/ha it remained 100% throughout the entire recording period (Table 2), equal to the effectiveness of the reference product. Pre-planting treatment of tubers was also carried out with a suspension concentrate, but containing 560 g of Acetamiprid/L instead of 180. Observations of aphids in the experimental treatments began from the moment they appeared on potato plants. The first aphids were recorded in the control on the 37th day after emergence. By the 40th day after emergence, aphids were observed in all treatments. High biological efficacy of the insecticide was observed at all application rates (Table 2). Visual observations revealed that, in the insecticide-treated plants, aphids that entered the treated plants and began feeding died shortly afterward.



Blue bars: Acetamiprid, KS (180 g/L) tubers; Red bars: Acetamiprid, KS (180 g/L) furrow; Green bars: Acetamiprid, VRK (180 g/L) furrow.

Figure 2. Bioefficiency of insecticides against aphids on potato crops.

During the growing season, potato plants were treated with an insecticide containing a high Acetamiprid content (water-dispersible granules—WDG, 560 g/l) at an application rate of 0.125 kg/ha. Biological efficacy was measured for three weeks after treatment: on the 3rd, 7th, 14th, and 21st days after treatment, it was 95.4%, 79.4%, 75.0%, and 63.0%, respectively. It is worth noting that, despite the highest Acetaprid content, the effectiveness of plant treatment during the growing season was inferior to the effectiveness of the insecticide application using the two methods described above. Thus, the presented results allow us to conclude that

acetamiprid-based products are universal and that various application technologies (taking into account environmental friendliness) can be effectively used against aphids on potatoes. The difficulty of using insecticides when growing potato mini tubers in protected soil is that treatments against aphids that carry viruses must be carried out separately.

Table 2. Biological efficiency of KS (560 g/l) in the control of aphids (family *Aphididae*) on potatoes (pre-planting treatment of tubers, Moscow region).

Option	Dosage rate of the drug, l/t	Reduction in the number of aphids relative to the control by days of counting after emergence, %			
		40	44	51	58
Acetamiprid, KS (560 g/l)	0.15	96.4	95.5	100	100
Acetamiprid, KS (560 g/l)	0.25	100	95.5	100	100
Acetamiprid, KS (560 g/l)	0.3	100	95.5	100	100
Standard cruiser, (300 g/l)	0.2	100	90.9	86.9	100
Health Care Pharmacy and Other services (HCP01)	-	7.7	2.1	1.6	0

There are no preparations in the State Catalogue of Pesticides and Agrochemicals approved for use in the Russian Federation for this greenhouse crop. In articles published in various journals, one can find not only chemical, but even biological preparations recommended by the authors, but they have never been registered not only for potatoes in protected ground, but also for other crops (kartofin, verticillin, etc.). In this study, we studied the effect of Acetamiprid, an aqueous solution (0.1 g/l), approved, on the one hand, for the control of aphids on vegetable and flower crops in protected ground, and on the other hand, on potatoes in open ground for the control of the Colorado potato beetle. Treatments in the greenhouse were carried out weekly, regardless of the number and species of aphids detected.

This was necessary because the danger lies not in the damage caused by the aphids, but in the viral infection they transmit. Even test injections of single individuals of non-specialized aphid species can lead to virus infection of potato plants. When growing minitubers, virus infection is unacceptable. An enzyme-linked immuno-sorbent assay (ELISA) for latent viral infection, conducted by the laboratory of the Russian Agricultural Center for the Moscow Region, was used to evaluate the effectiveness of the studied aqueous acetamiprid solution, both during the flowering phase (leaves) and in minitubers after harvest. No latent viral infection was detected in the test plants or the resulting tubers.

4. Conclusions

The research results allowed us to draw a conclusion about the effectiveness of using Acetamiprid in various technologies for protecting seed potatoes from aphids—virus carriers—in open ground and greenhouses. The Acetamiprid is a

neonicotinoid insecticide which has demonstrated high efficacy in controlling potato aphids (*Macrosiphum euphorbiae*) from 67.4% to 100% during the recording period for the 0.5 l/ha application rate, while at 1.0 l/ha it remained 100% throughout the entire recording period. Aphids are key pests in potato cultivation due to their role in direct feeding damage and virus transmission like Potato virus Y. Field and laboratory studies consistently show that Acetamiprid provides rapid knockdown and prolonged residual activity against aphid populations, even at low application rates. Its systemic nature allows for uptake by the plant, offering protection to new growth and effectively reducing aphid colonization and reproduction.

However, repeated and exclusive use of Acetamiprid can lead to the development of resistance in aphid populations, diminishing its long-term effectiveness. Therefore, integrated pest management (IPM) strategies that combine acetamiprid with cultural practices, biological control agents (lady beetles, parasitoid wasps), and rotation with insecticides of different modes of action are recommended to sustain its efficacy and minimize ecological impact. The possibility of effective use of various technologies for applying the insecticide against aphids on seed potatoes both in open and protected ground in the Moscow region.

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Conflicts of Interest

The authors declare no conflicts of interest.

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