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IMPLEMENTATION OF NEW TECHNOLOGIES IN THE RED SOILS OF ADJARA (WITHOUT THE USE OF MINERAL FERTILIZERS)

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Abstract. *To prevent soil contamination and to obtain environmentally safe agricultural products, ecologically safe biopreparations – BlackJack, GeoHumate, and the insecticide Cu^{++}were purposefully introduced for the first time into stationary field experiments conducted on red soils of Adjara under mandarin (Citrus unshiu) plantations, without the application of mineral fertilizers.*

The field experiments were conducted on the Chakvi collection plots located on red soil under a mandarin (Citrus unshiu, broadleaf type) plantation. The trials were arranged in three replications, comprising a total of six model plants, while each treatment variant included nine plants. Prior to the establishment of the experiment and throughout its duration, soil samples were collected at a depth of 50 cm, along with leaf samples from the plants, to determine their biochemical parameters. During the experimental period, pest and disease monitoring was performed twice.

The experimental design consisted of three treatment variants. The biofertilizers were applied according to the scheme four times during the vegetation period (April, May, June, and July). As a background treatment, the Cu^{++} insecticide was applied both to the soil (by drenching) and to the plants (by foliar spraying), exerting a positive effect on pest and disease suppression.

Multiple monitoring activities conducted throughout the vegetation period revealed the positive influence of the applied bioformulations. Based on the data obtained from the experiments, the following results were established:

- *The biofertilizers BlackJack (soil application and foliar spraying) and GeoHumate (soil application and foliar spraying), when used in combination with Cu^{++} (2 mL per 10 L of water as foliar spray) and without the use of mineral fertilizers, demonstrated the best overall performance.*
- *Soil fertility improved significantly, and the content of essential nutrients in plant leaves increased.*
- *Throughout the vegetation period, the positive effect of the applied preparations was consistently observed.*
- *Pest- and disease-induced plant damage was eliminated, and most importantly, a high-yielding, environmentally clean, and high-quality harvest was obtained.*

According to the data presented in the tables, toxic elements such as As, Cd, Cr, Hg, and Pb were not detected in the soil, and consequently, were also absent in the plants and fruit. This outcome is attributed to the fact that the soil was enriched exclusively with ecologically clean fertilizers, thereby preventing contamination of the low-fertility red soils of Adjara.

Key words: *biofertilizer, red soil, citrus, toxic elements, ecological safety*

Introduction

Soil is the source of life, a mixture of minerals and organic matter that determines plant germination and growth. It directly influences the food consumed by humans, the water they drink, the air they breathe, as well as the flora, fauna, and human health. Consequently, soil pollution triggers chain reactions that adversely affect all other environmental components.

With the growth of industrialization, the harmful impact of industrial waste on the environment has significantly increased, particularly affecting water and soil, where heavy metals tend to accumulate. Contamination of soil and water by heavy metals has become a serious global environmental issue.

Addressing soil contamination requires considerable time, resources, and effort, as it poses both environmental and public health challenges. Over the years, various methods and technologies have been introduced to combat this problem [1].

With the growth of the human population, the demand for food is constantly increasing, yet food production is impossible without soil. Healthy soil ensures healthy food, which is why it is essential to devote particular attention to soil care and fertility management, especially today, when soil contamination has become a pressing global issue.

Plants grown on polluted soil can accumulate excessive amounts of toxic elements, including mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb). The accumulation of these elements in soil leads to soil pollution, which in turn poses a serious threat to flora, fauna, and human health [4].

Excessive accumulation of heavy metals presents significant health risks to humans. For instance, cadmium uptake can cause severe disorders such as cancer and bone demineralization, among others. Lead is particularly hazardous for children, as it damages brain cells and the central nervous system.

Excessive application of chemical fertilizers may also impair soil microbial activity, reducing the ability of bacteria to decompose organic matter and to produce vital nutrients essential for plant growth. Similarly, pesticides negatively affect beneficial soil bacteria and other important organisms [5].

Therefore, to prevent soil contamination and to produce environmentally safe agricultural products, we conducted, for the first time, stationary field experiments on the red soils of Adjara under mandarin (Citrus unshiu) plantations. The experiments involved the targeted application of ecologically safe biopreparations, BlackJack, GeoHumate, and the Cu^{++} insecticide, without the use of mineral fertilizers.

BlackJack is a 100% natural product, certified in Germany for organic agriculture. It is an innovative formulation distinguished from other preparations by its content of humic and ulmic acids – compounds that stimulate and activate plant root and vegetative systems. In addition, it reduces salt concentration, enhances the adsorption of nutrients, increases the activity of beneficial microelements, and acts as a carrier agent for micro- and macro-nutrients, facilitating their transformation into more bioavailable forms and their uniform distribution throughout the plant.

BlackJack can be applied both as a foliar spray and through drip irrigation systems. It may be used alone or in combination with other agents.

- Foliar feeding: 10 mL dissolved in 2 L of water per plant; application interval: every 10–15 days.
- Root feeding: 10 mL dissolved in 1.5 L of water per plant; application interval: every 10–15 days.

GeoHumate is an ecologically clean humic biofertilizer, rich in microelements, and often referred to as a plant growth stimulator. It helps to alleviate plant stress, promotes green mass development, bud formation, and prolonged, abundant flowering. GeoHumate is used for comprehensive nutrition of agricultural crops, beginning with seed treatment and continuing with subsequent plant applications. It is particularly effective when used via drip irrigation systems, both in open-field and greenhouse conditions.

- Foliar application: four treatments are recommended during the vegetation period; dilution rate: 5 mL per 1 L of water per plant.

Cu^{++} (Copper) is essential for the functioning of the plant immune system. It serves as a catalyst in photosynthetic reactions, promotes lignin synthesis, and supports protein metabolism and respiratory activity. Copper also enhances the plant's resistance to pests and diseases.

- Recommended dosage: 10 mL dissolved in 3.5 L of water.

The field experiments were conducted on the Chakvi collection plots located on red soils under a mandarin (Citrus unshiu, broadleaf type) plantation. The trials were arranged in three replications, comprising a total of six model plants, while each variant included nine plants. Prior to and during the experiment, soil samples were collected from a 50 cm depth, and leaf samples were taken to determine biochemical parameters. During the experimental period, pest and disease incidence was monitored twice.

The experimental design included three variants. The biofertilizers were applied four times during the vegetation period (April, May, June, and July) in accordance with the established scheme.

The experiments were established according to the following scheme:

1. BlackJack – applied both as foliar spray and soil drench (8 mL dissolved in 2 L of water per plant; application interval: every 10–15 days). Cu^{++} (10 mg dissolved in 3.5 L of water) applied as foliar spray.

2. GeoHumate – applied both as foliar spray and soil drench (5 mL dissolved in 1 L of water per plant; application interval: every 10–15 days). Cu^{++} (10 mg dissolved in 3.5 L of water) applied as foliar spray.
3. Control (without biofertilizers)

After the experimental treatments, a multi-element analysis of the soil water extract was performed to determine the macro- and microelement composition. The analytical results are presented in Table 1.

Table 1. Results of multi-element analysis in the soil water extract (red soil, Chakvi site, 08.07.2025)

Element	Concentration (mg/L)	Element	Concentration (mg/L)	Element	Concentration (mg/L)
Al	1.81	**As**	-0.0107	**B**	0.327
Ba	0.0031	**Be**	0.0012 L	**Ca**	9.98
Cd	-0.0201	**Co**	-0.0122	**Cr**	-0.0475
Cu	-0.0998	**Fe**	3.18	**Hg**	-2.43
K	3.13	**Li**	1.99	**Mg**	2.80
Mn	0.0144	**Mo**	-0.0299	**Na**	-0.364
Ni	0.0008	**P**	0.392 L	**Pb**	-0.155
Sb	-0.0862	**Se**	0.0194 L	**Si**	59.2
Ti	0.175	**Tl**	-0.0107	**V**	-0.154
Zn	-0.0341				

Emphasis was placed on determining the content of toxic elements – arsenic (As), cadmium (Cd), chromium (Cr), mercury (Hg), nickel (Ni), and lead (Pb) which are primarily responsible for soil contamination.

Specifically, the measured concentrations of these elements in the soil water extract were as follows: As – 0.011 mg/L, Cd – 0.020 mg/L, Cr – 0.046 mg/L, Hg – trace, Ni – 0.0008 mg/L, and Pb – 0.155 mg/L.

These results indicate that the concentrations of toxic heavy metals are extremely low, remaining below internationally accepted threshold limits, thereby confirming the absence of contamination and the ecological safety of the studied soils.

To further assess the effect of biofertilizer application, mandarin leaf samples were collected after treatment. The chemical composition (macro- and microelements) of the leaves was analyzed, and the results are presented in Table 2.

Chemical Composition of Mandarin Leaves (Macro- and Microelements) After Biofertilizer Application (22–28 August 2025)

Table 2. Composition of macro- and microelements in mandarin leaves following the application of biofertilizers.

Variant	Al (mg/L)	As (mg/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Ca (mg/L)	Cd (mg/L)	Co (mg/L)	Cr (mg/L)
BlackJack (20 mL per 3 L of water, applied to soil and foliage) + Cu^{++} (20 mL per 10 L of water, foliar spray)	54.4	-0.0723	15.0	30.0	0.0020L	2043.37	-0.0216	-0.0206	-0.083
GeoHumate (15 mL per 3 L of water, applied to soil and foliage) + Cu^{++} (20 mL per 10 L of water, foliar spray)	66.3	-0.0618	17.7	40.5	0.0021 L	2174.00	-0.0238	-0.0264	-0.049
Without biofertilizers (control)	27.9	-0.102	8.4	18.4	0.0009 L	1985.40	-0.0284	-0.0284	-0.0487

Table 3. Concentration of additional macro- and microelements in mandarin leaves after biofertilizer application (22–28 August 2025)

Variant	Cu (mg/L)	Fe (mg/L)	Hg (mg/L)	K (mg/L)	Li (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)
BlackJack (20 mL per 3 L of water, applied to soil and foliage) + Cu^{++} (20 mL per 10 L of water, foliar spray)	17.1	31.6	-11.4	3400	-2.33	844	8.58	-0.095	311
GeoHumate (15 mL per 3 L of water, applied to soil and foliage) + Cu^{++} (20 mL per 10 L of water, foliar spray)	36.4	35.4	-11.7	3760	-1.45	951	10.7	-0.0321	427
Without biofertilizers (control)	4.32	16.9	-7.7	2590	-3.44	608	4.19	-0.0358	372

Table 4. Concentration of trace elements in mandarin leaves after biofertilizer application (22–28 August 2025)

Variant	Ni (mg/L)	P (mg/L)	Pb (mg/L)	Sb (mg/L)	Se (mg/L)	Si (mg/L)	Ti (mg/L)	Tl (mg/L)	V (mg/L)	Zn (mg/L)
BlackJack (20 mL/3 L water, soil + foliar application) + Cu^{++} (20 mL/10 L water, foliar spray)	1.28	978	-0.12	-0.452	0.227 L	198	-0.0816 L	-0.22	-0.0177	7.20
GeoHumate (15 mL/3 L water, soil + foliar application) + Cu^{++} (20 mL/10 L water, foliar spray)	1.35	1280	-0.105	-0.277	0.120 L	254	-0.0244 L	-0.299	-0.0165	9.08
Without biofertilizers (Control)	0.575	766	-0.251	-0.426	0.144 L	99.4	0.0387 L	-0.284	-0.0338	3.59

The toxic elements, As, Hg, Cd, Sb, Pb, and Ni, were not detected in the mandarin leaves. As a background treatment, the Cu^{++} insecticide was applied both to the soil (by drenching) and to the plants (by foliar spraying), which also exerted a positive effect on the suppression of pest and disease incidence. Multiple monitoring sessions conducted during the vegetation period confirmed the positive influence of the applied preparations on plant health and development.

The soil and plant analyses were performed at the Institute of Agrarian and Membrane Technologies, within the Laboratory of Agrochemistry and Soil Science, using a plasma atomic emission spectrophotometer (ICPE-9820). Analyses were carried out under both wet and dry ashing conditions [2,3].

Based on three years of experimental data, we can now provide scientifically validated recommendations and methodological guidelines. The results obtained can be effectively used by farmers, as well as by research centers and professionals in related fields, biochemists, biologists, agrochemists, soil scientists, and entomologists to prevent soil contamination. It is recommended that only the identified ecologically clean biofertilizers be used to achieve environmentally safe, high-quality yields.

Conclusions

Based on the results obtained from the experiments conducted, the following conclusions were drawn:

- The applied biofertilizers BlackJack (soil and foliar application) and GeoHumate (soil and foliar application) in combination with Cu^{++} (2 mL per 10 L of water, foliar spray), without the use of mineral fertilizers, produced the best overall results.
- Soil fertility improved significantly.
- The concentration of essential nutrient elements in mandarin leaves increased.

- During the vegetation period, a positive effect of the applied formulations was observed, and plant diseases and pest infestations were effectively suppressed.
- Most importantly, a high, ecologically clean, and high-quality yield was obtained.

According to the analytical data presented in the tables, no pesticide residues or toxic elements such as As, Cd, Cr, Hg, or Pb were detected in the soil, plants, or fruit. This confirms that the soil was enriched exclusively with environmentally safe fertilizers, thereby preventing contamination of the low-fertility red soils of Adjara.

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