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RESEARCH ARTICLE

Comparative analysis of agrochemical, allelopathic and microbiological characteristics of the soil environment for *Actinidia arguta* (Siebold et Zucc.) Planch. ex Miq. cultivated in Ukraine and two provinces of China

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Abstract

The objective of this study was to evaluate agrochemical, allelopathic and microbiological characteristics of the soil under *Actinidia arguta* plants cultivated in Ukraine and two provinces of China.

Material and methods. The rhizosphere soil was sampled at 0–15 cm layer under *A. arguta* plants in the stage of fruit ripening in Ukraine (Kyiv city: North of Ukraine, Forest-Steppe zone, a temperate continental climate) and two provinces of China (Shandong: East China, a temperate monsoon zone; and Heilongjiang: Northeast China, continental monsoon climate). The concentrations of carbon, available forms of macro- and micronutrients, phenolic compounds in the soil samples were determined. pH and redox potential of soil were measured. Soil phytotoxicity was studied by direct bioassay method on cress (*Lepidium sativum*) root growth. Microbiological analyses of soil samples were conducted.

Results. The dissimilarities in the concentrations of carbon, macro- and micronutrients in the examined soil samples were shown. The reduction conditions (Eh < 400 mV) in the soils under *A. arguta* might slow down the humification processes. A similar effect may be caused by mobile forms of organic compounds with allelopathic properties. The redox potential decreased with the increase of pH values. This fact reflects the intensifying of reduction processes. The soil phytotoxicity under *A. arguta* reached 20–70 % compared with the control, probably due to the accumulation of phenolic compounds, as well as iron and manganese. In soils under *A. arguta*, the relationship between pH, phytotoxicity, and the abundance of main taxonomical and ecotrophic groups of microorganisms was evaluated.

Conclusions. Calcic Luvisols from the M.M. Gryshko National Botanical Garden of the NAS of Ukraine (Kyiv city, Ukraine) and Luvic Chernozems from Jiamusi (Heilongjiang province, China) were determined to be the most favorable for *A. arguta* cultivation. Salic Solonetz from Harbin (Heilongjiang province, China) and Haplic Luvisols from Linyi (Shandong province, China) had the least suitable soil conditions for *A. arguta*.

Keywords: agrochemicals, phenolic allelochemicals, phytotoxicity, microorganisms, micromycetes, bacteria

Introduction

The natural area of *Actinidia arguta* (Siebold et Zucc.) Planch. ex Miq. (hardy kiwifruit) includes China, Korea, and Japan (Park, 2017). In recent times, the cultivation of hardy kiwifruit has spread far away from these countries. This species have commercial importance due to its high adaptability, productivity, and various uses

(Drzewiecki et al., 2016; Stefaniak et al., 2017a; Latocha, 2017; Almeida et al., 2018).

In particular, in Ukraine, introductory studies with A. *arguta* were initiated by M. Kaschenko, a member of the Academy of Sciences of Ukrainian SSR, in the Acclimatization Garden (Kyiv) in the 1920s (Skrypchenko & Latocha, 2017). A. *arguta* has been successfully cultivated since the 1950s in the M.M. Gryshko National Botanical Garden of the NAS of Ukraine, where its anatomical, morphological and biochemical features, regenerative ability under conditions of introduction are investigated, and also selection work is carried out (Skrypchenko, 2002; Skrypchenko & Latocha, 2017).

Actinidia arguta is mainly cultivated as a fruit and honey plant because it has beneficial nutritional qualities due to the high content of vitamins and mineral elements, as well as dietary properties (Park, 2017; Latocha, 2017; Pinto & Vilela, 2018; Almeida et al., 2018). Wide range of bioactive compounds with antiproliferative (Zuo et al., 2012; Latocha, 2017), antioxidant (Zuo et al., 2012; Mikami-Konishide et al., 2013; Latocha, 2017; Almeida et al., 2018), antimicrobial (Almeida et al., 2018), hepatoprotective (Jho et al., 2011), antiallergic (Latocha, 2017), anti-inflammatory and antinociceptive (Teng et al., 2013), antiamnesic (Ha et al., 2015) and some other effects (Nishimura et al., 2016; Latocha, 2017) makes hardy kiwifruit the high-value medicinal plant.

Investigations of the soil environment of kiwifruit are fragmentary in contrast to its well-studied biological properties (Richards et al., 2007; Li et al., 2017a; Stefaniak et al., 2017b). This fact motivated us to pay attention to the study of the soil properties under A. *arguta* in the centers of its introduction (Ukraine) and natural habitat (China). We hypothesized that the relations between agrochemicals, allelochemicals, and soil microbiota determine the success of the introduction and cultivation of A. *arguta* plants. An analytical assessment of the characteristics of the soil under A. *arguta* plants in Ukraine and the provinces of China will help to determine the optimal conditions for its cultivation. This approach will provide opportunities for the interchange of A. *arguta* cultivars of local selection in the future.

The objective of this study was to evaluate agrochemical, allelopathic and microbiological characteristics of the soils under A. *arguta* plants in Ukraine and two provinces of China.

Material and methods

The rhizosphere soil was sampled at 0–15 cm layer under A. *arguta* plants in the stage of fruit ripening. This stage completes the generative period of development. It is the most important in the ontogenesis of fruit plants, in particular, of A. *arguta*.

The analysis was conducted on: 1 – Haplic Luvisols, Linyi (Shandong province: East China, monsoon temperate zone); 2 – Salic Solonetz, formed by the hydrolysis of carbonates (Na_2CO_3, $NaHCO_3$), Harbin (Heilongjiang province: Northeast China, continental monsoon climate), 3 – Luvic Chernozems, Jiamusi (Heilongjiang province: Northeast China, continental monsoon climate), 4 – Calcic Luvisols, M.M. Gryshko National Botanical Garden of the NAS of Ukraine (NBG, Kyiv: North of Ukraine, Forest-Steppe zone, temperate continental climate). The soils were classified according to the IUSS Working Group WRB (2015).

Air-dry soil samples were sieved using a 1 mm diameter sieve. Available forms of macro- (N, P, K) and micronutrients (Fe, Mn) were extracted with 1M HCl from air-dry soil (Rinkis & Nollendorf, 1982). The concentrations of carbon and nitrogen in the soil samples were determined as described by Rinkis & Nollendorf (1982). Qualitative and quantitative analysis of P, K, Fe, and Mn was performed using Thermo Scientific iCAP 6300 ICP (Inductively Coupled Plasma) Spectrometer. Soil pH was measured with HI 2211 (Hanna instruments, pH/ORP Meter) according to the State Standard of Ukraine (2003), ISO 1039-2001. The pH was determined using a 1M KCl solution.

Phenolic compounds were extracted from the soil by desorption method using an ion exchanger KU-2-8 (H^+) (Grodzinskij et al., 1988). The contact of the soil with the resin (KU-2-8 (H^+)) was held in a flat-bottomed flask with a ground stopper in a neutral medium (ethyl alcohol) at a ratio of soil : resin : alcohol – 1:1:2. The contents of the flask were well stirred and allowed to contact for 48 hours. After that, the eluates were separated by centrifugation at 6000 rpm for 20 minutes.

Table 1. Agrochemical characteristics of soils under *Actinidia arguta* plants, air-dried samples.

Soil samples	pH (1M KCl)			Available nutrients, mg·g^{-1}					C, %
	Min	Max	Mean	N	P	K	Fe	Mn	
Linyi, Shandong province (Haplic Luvisols)	3.9	4.4	4.2	0.26 ± 0.08	0.84 ± 0.05	1.37 ± 0.04	5.00 ± 0.04	0.70 ± 0.02	1.1
Harbin, Heilongjiang province (Salic Solonetz)	7.8	8.5	8.3	0.24 ± 0.04	0.11 ± 0.02	3.62 ± 0.06	4.37 ± 0.07	0.30 ± 0.02	2.6
Jiamusi, Heilongjiang province (Luvic Chernozems)	4.7	5.9	5.6	0.28 ± 0.06	0.28 ± 0.09	4.57 ± 0.09	15.0 ± 0.08	0.25 ± 0.08	3.9
NBG, Kyiv (Calcic Luvisols)	6.9	7.5	7.3	0.17 ± 0.05	0.22 ± 0.02	2.35 ± 0.01	4.60 ± 0.06	0.24 ± 0.01	3.6

After removal of the supernatant liquid, the contents of the centrifuge tubes were washed with ethyl alcohol. Then elution continued for 18 hours. Subsequently, the extraction was carried out in the same sequence twice with aqueous acetone (2:1 by volume). The eluates were concentrated on a water bath. The dry residues of alcohol and water-acetone eluates were dissolved in 5 ml of 96 % and 10 ml of 48 % ethanol, respectively. The content of phenolic compounds in the obtained alcohol solutions of two eluates (alcohol and water-acetone) was measured spectrophotometrically at 730 nm wavelength using Folin-Ciocalteu reagent. The total amount of phenolic compounds was expressed as gallic acid equivalent.

Soil phytotoxicity was studied by direct bioassay method on cress (*Lepidium sativum* L.) root growth (Grodzinskij et al., 1990). The redox potential (Eh) was measured in soil suspension, as a model of soil solution, at the soil to distilled water ratio as 1:1 by potentiometric technique (Fiedler et al., 2007; Labuda & Vetchinnikov, 2011).

For the microbiological analyses, such as the determination of the abundance of micromycetes (Czapek medium), ammonifiers (meat-peptone agar), microbiota, utilizing inorganic nitrogen, and actinomycetes (ammonium starch agar) the conventional methods were applied (Tepper et al., 2004). To determine the ratio between the separate ecotrophic groups, we calculated the mineralization-immobilization coefficient, following the methods of Andreiuk et al. (2001), and the calculation of SOM (soil organic matter) transformation index was based on Mukha (1980).

A one-way analysis of variance (ANOVA) was performed to determine the effect of factors such as pH and phytotoxicity on agrochemical, allelopathic, and microbiological characteristics of the soil. The probability of influence factors was estimated by the significance level (P) and Fisher's test (F). The data presented in the tables and figures are averages and standard deviation of the mean (SD). Five replicates were used in each treatment. Experimental data were statistically analyzed using Statistica 10.0 and Microsoft Excel software.

Results and discussion

The investigation of the soil samples under hardy kiwifruit indicates various carbon concentrations in the different habitats. The lowest value of carbon concentration was detected in Haplic Luvisols from Linyi (Table 1). Salic Solonetz from Harbin contained 2.5 times more carbon than Haplic Luvisols. The carbon concentration was higher in Luvic Chernozems from Jiamusi and Calcic Luvisols from NBG (Kyiv).

Soil with the pH 5.5–6.0 is suggested to be the best for the hardy kiwifruit cultivation (Strik, 2005). Thus, Luvic Chernozems (Jiamusi) is the most suitable for the cultivation of hardy kiwifruit, in contrast to Salic Solonetz from Harbin with alkaline reaction. The last can be considered as unfavorable for this crop

Table 2. ANOVA results. The effect of pH on the agrochemical, allelopathic, and microbiological characteristics of the soil.

Indicator	SS effect	df effect	MS effect	SS error	df error	MS error	F	P
N	33639	16	2102	3458	3	1152.5	1.8243	0.34347
P	1581806	16	98863	8251	3	2750.3	35.9458	0.00651
K	27200292	16	1700018	1807871	3	602623.5	2.8210	0.21345
Fe	447666539	16	27979159	146321	3	48773.7	573.6530	0.00010
Mn	752134	16	47008	2243	3	747.7	62.8734	0.00285
C	2275	16	142	91	3	30.3	4.6875	0.114310
Eh	216656	16	13541	40406	3	13468.5	11.0054	0.00580
Phenolics	151381	16	9461	83233	3	27744.3	0.3410	0.93467
Micromycetes	14329	16	896	132	3	44.0	20.3537	0.01494
Actinomycetes	122	16	8	93	3	30.8	0.2474	0.97430
Ammonifiers	684	16	43	85	3	28.3	1.5078	0.41333
Inorganic nitrogen consumers	2233	16	140	859	3	286.3	0.4874	0.85288
Soil phytotoxicity	401401	16	25088	245026	3	81675.2	0.3072	0.95071

Note: SS – the sum of squares, **df** – degrees of freedom, **MS** – the mean sum of squares, **F** – Fisher's test, **P** – significance level.

because the availability of nutrients varies with pH. The availability of nitrogen and phosphorus decreases at pH ≥ 8. Salic Solonetz from Harbin contained the lowest phosphorus concentration among the tested samples.

As one of the vital nutrients, potassium is essential for the soil water regime. A. *arguta* was reported to be rich in potassium (Latocha, 2017). Haplic Luvisols from Linyi was characterized by 1.7–3.3 times lower concentration of potassium as compared to the rest of the analyzed soil samples. Moreover, the content of this nutrient was probably affected by the soil texture. Clay, loam, and heavy sandy-loam soils tend toward higher levels of potassium than sandy and sandy-loam ones.

Relationships between pH and soil-forming environmental factors (climate, parent material, and topography) in Southwestern China were previously observed (Zhang et al., 2019). Soil pH affects the mobility and bioavailability of nutrients, microbiological activity, plant growth, and development (Neina, 2019). Therefore, we analyzed the relationships between soil pH and agrochemical, microbiological and allelopathic characteristics of the studied soils. Results of the analysis of variance (ANOVA) showed that pH factor significantly affected the soil agrochemical characteristics such as the concentrations of phosphorus, iron, and manganese (Table 2). Phosphorus concentration prevailed in Haplic Luvisols from Linyi. At the same time, low pH reduced the availability of several nutrients, particularly phosphorus. The highest level of iron was in Luvic Chernozems from Jiamusi. The maximum concentration of manganese in Haplic Luvisols from Linyi was observed. Low pH values raised the solubility of toxic forms of iron and manganese, which can have an unfavorable impact on plant growth and development.

The biochemical state of the soil was evaluated by the values of the oxidation-reduction potential (redox potential or Eh). Soil Eh is dynamic and dependent on many factors, i.e., aeration, temperature, humidity, organic matter, the enzyme activity of microorganisms (Husson, 2013). Redox potential is used as an indicator of the content of biogenic forms and toxins in the soil environment (Husson, 2013).

It was shown that the reduction processes of different intensity levels were dominant in soil samples under A. *arguta*. The pH factor contributed to the change in the Eh values

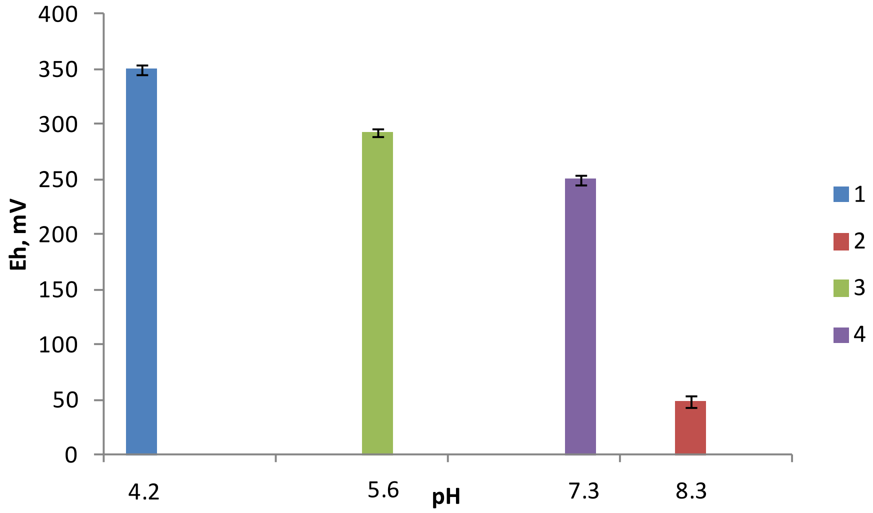

Figure 1. The value of the redox potential (Eh) with different pH of soil under *Actinidia arguta* plants, mV: **1** – Haplic Luvisols, Linyi (Shandong province, China); **2** – Salic Solonetz, Harbin (Heilongjiang province, China); **3** – Luvic Chernozems, Jiamusi (Heilongjiang province, China); **4** – Calcic Luvisols, NBG (Kyiv, Ukraine). Error bars: SD (standard deviation of the mean), n = 5.

(Table 2). Moreover, the redox potential decreased with the increase of pH values (Fig. 1). This fact reflects the intensifying in reduction processes. Thus, the maximum reduction was recorded in the soil from Harbin, which was characterized by an alkaline reaction. The observed tendency was also described for other types of soil (Husson, 2013). The observed reduction conditions (Eh < 400 mV) in the investigated soils indicated a slowdown in the humification process. It also may reflect the presence of mobile forms of organic compounds that can be involved in allelopathic interactions.

Phenolic compounds are considered to be one of the essential classes of allelochemicals. They are widespread in the plant world and have versatile effects on crucial physiological and biochemical processes such as respiration, photosynthesis, growth, and development (Li et al., 2010).

Fruits, leaves, and roots of A. *arguta* have a high content of phenolic compounds with allelopathic effects, that can be released into the root environment by leaching, decay of plant residues or in the form of root exudates (Zuo et al., 2012; Teng et al., 2013; Nishimura et al., 2016; Park, 2017; Latocha, 2017; Almeida et al., 2018; Li et al., 2018). The most important of them are flavan-3-ols, flavonols, phenolic acids, and anthocyanins, in particular, such as quercetin and kaempherol derivatives, as well as hydroxycinnamic acid derivatives, gallic, caffeic, chlorogenic, 2,4-dihydroxybenzoic acids, catechin, epicatechin and rutin (Latocha, 2017; Almeida et al., 2018).

Therefore, we considered it necessary to investigate the concentration of phenolic compounds in the rhizosphere soil of A. *arguta*. The investigated soils differed in the concentration of phenolic compounds (Fig. 2). Their lowest concentration was determined in the soil from M.M. Gryshko National Botanical Garden. In the soils from Harbin and Linyi, the total concentration of phenolic compounds prevailed. It should be noted that these soil samples were characterized by the lowest carbon content (Table 1).

The accumulation of free phenolic compounds was due to a violation of the humification process. At the same time, the dominance of intensively reducing conditions in the soil from Harbin contributed to the formation of the highest amount of organic substances with phenolic groups.

The soil phytotoxicity under the plants of A. *arguta* reached 20–70 % compared to the control (Fig. 3). It was the smallest for Calcic Luvisols from NBG and the largest for Salic Solonetz from Harbin.

Soil phytotoxicity factor showed the most substantial effect on the concentrations of phenolic compounds, iron, and manganese (Table 3). The effect of the phytotoxicity factor was the greatest concerning the accumulation of phenolic allelochemicals.

The soil microbiota provides the decomposition of the complex organic

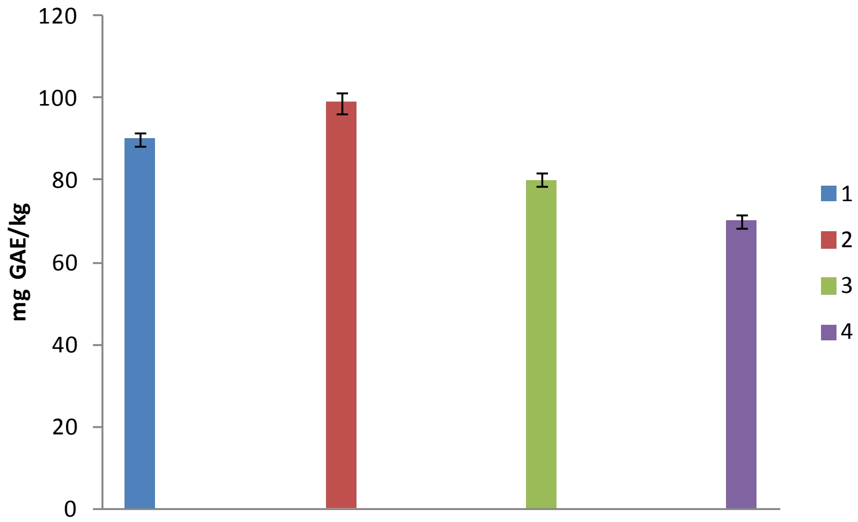

Figure 2. Phenolic compounds concentration in soil under *Actinidia arguta* plants, mg GAE (gallic acid equivalent)/kg: **1** – Haplic Luvisols, Linyi (Shandong province, China); **2** – Salic Solonetz, Harbin (Heilongjiang province, China); **3** – Luvic Chernozems, Jiamusi (Heilongjiang province, China); **4** – Calcic Luvisols, NBG (Kyiv, Ukraine). Error bars: SD (standard deviation of the mean), n = 5.

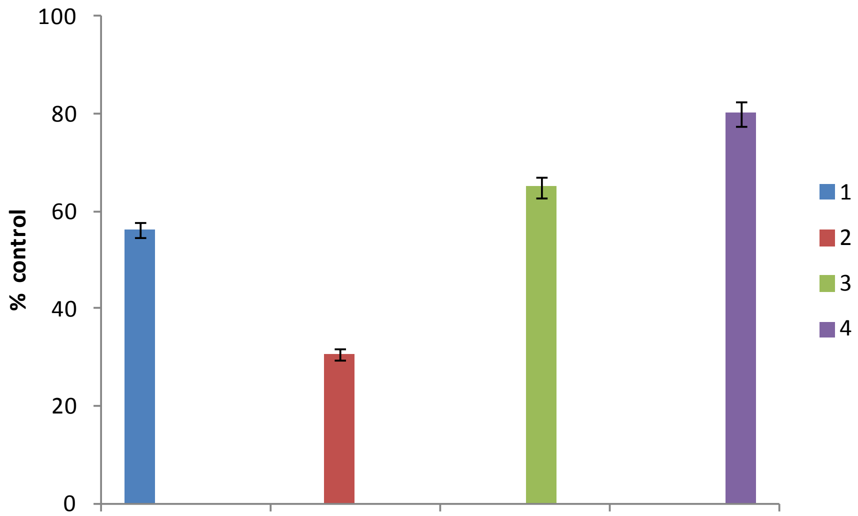

Figure 3. Soil phytotoxicity under *Actinidia arguta* plants (bioassay – roots growth of *Lepidium sativum*), % control: **1** – Haplic Luvisols, Linyi (Shandong province, China); **2** – Salic Solonetz, Harbin (Heilongjiang province, China); **3** – Luvic Chernozems, Jiamusi (Heilongjiang province, China); **4** – Calcic Luvisols, NBG (Kyiv, Ukraine). Error bars: SD (standard deviation of the mean), n = 5.

compounds into the nutrients available for plants (Li et al., 2017b). Consequently, the study of microbiocoenosis allows to understand the direction of microbiological processes and to predict changes in soil conditions, which can be used to create and to improve crop cultivation techniques. In turn, these benefits sustain the conservation and remediation of soil fertility as the prerequisite for good productivity of the whole agro-ecosystem. Chinese researchers observed that soil treatment with beneficial microbiota increased the kiwifruit yield and enhanced the crop resistance for diseases (Li et al., 2017a). Nevertheless, there is no data about the abundance of main taxonomical and ecological trophic groups of microbiota as well as the direction of microbiologic processes in soils under A. *arguta*.

pH factor significantly influenced the abundance of micromycetes (Table 2). Among the samples from the several Chinese provinces, Haplic Luvisols from Linyi was characterized with the highest abundance of micromycetes (Table 4). Therefore, this trend was the consequence of the lowest pH (4.2) of the corresponded plot (Table 1).

Table 3. ANOVA results. The effect of phytotoxicity on the agrochemical, allelopathic, and microbiological characteristics of the soil.

Indicator	SS effect	df effect	MS effect	SS error	df error	MS error	F	P
N	34674	11	3152	2423.0	8	302.88	10.41	0.001359
P	1586954	11	144269	3102.5	8	387.81	372.01	0.000000
K	28645457	11	2604132	362705.5	8	45338.19	57.44	0.000002
Fe	447189507	11	40653592	623353	8	77919.13	521.74	0.000000
Mn	749124	11	68102	5252.5	8	656.56	503.73	0.000000
C	2362	11	215	4.0	8	0.50	429.45	0.000000
Eh	591377	11	28161	437506.0	8	7172.00	3.92637	0.000015
Phenolics	234601	11	21327	12.5	8	1.56	13649.53	0.000000
Micromycetes	14107	11	1282	354.0	8	44.25	28.98	0.000031
Actinomycetes	202	11	18	13.0	8	1.63	11.28	0.001024
Ammonifiers	688	11	63	81.0	8	10.13	6.17	0.007905
Inorganic nitrogen consumers	2984	11	271	107.5	8	13.44	20.19	0.000122
pH	5456	11	496	221.0	8	27.63	17.96	0.000189

Note: SS – the sum of squares, **df** – degrees of freedom, **MS** – the mean sum of squares, **F** – Fisher's test, **P** – significance level.

Table 4. The abundance of the main taxonomical and ecotrophic groups of microbiota in soils under *Actinidia arguta* plants.

Soil samples	Micromycetes, $\times 10^3$ CFU	Actinomycetes, $\times 10^6$ CFU	Ammonifiers, $\times 10^6$ CFU	Inorganic nitrogen consumers, $\times 10^6$ CFU	Coefficient of mineralization-immobilization of nitrogen	SOM transformation index
Linyi, Shandong province (Haplic Luvisols)	88.1 ± 4.8	0.5 ± 0.1	4.2 ± 0.3	3.6 ± 0.4	0.9	8.7
Harbin, Heilongjiang province (Salic Solonetz)	15.0 ± 1.6	0.3 ± 0.1	3.2 ± 0.05	3.7 ± 0.4	1.2	5.8
Jiamusi, Heilongjiang province (Luvic Chernozems)	46.4 ± 16.3	0.5 ± 0.1	3.9 ± 0.8	5.9 ± 0.5	1.5	6.5
NBG, Kyiv (Calcic Luvisols)	26.3 ± 4.8	1.2 ± 0.1	4.4 ± 1.0	7.1 ± 0.1	1.6	7.1

Note: CFU – colony-forming unit, **SOM** – soil organic matter.

Luvic Chernozems from Jiamusi with weakly acid reaction was rich in soil fungi, and Salic Solonetz from Harbin with weakly alkaline reaction was deficient in them (Fig. 4). Soil samples from NBG outstood with the lowest abundance of this microbiota group, but the higher level of actinomycetes as compare with Chinese samples (Fig. 5). Among the studied groups of microbiota, the abundance of micromycetes was the most sensitive to soil phytotoxicity (Table 3). Ammonifiers showed the least response to soil phytotoxicity.

It was observed the slight difference of ammonifier abundance between the analyzed samples. The soil from Harbin was the poorest, and from NBG was the richest in this group of the microbiota. At the same time, nitrogen

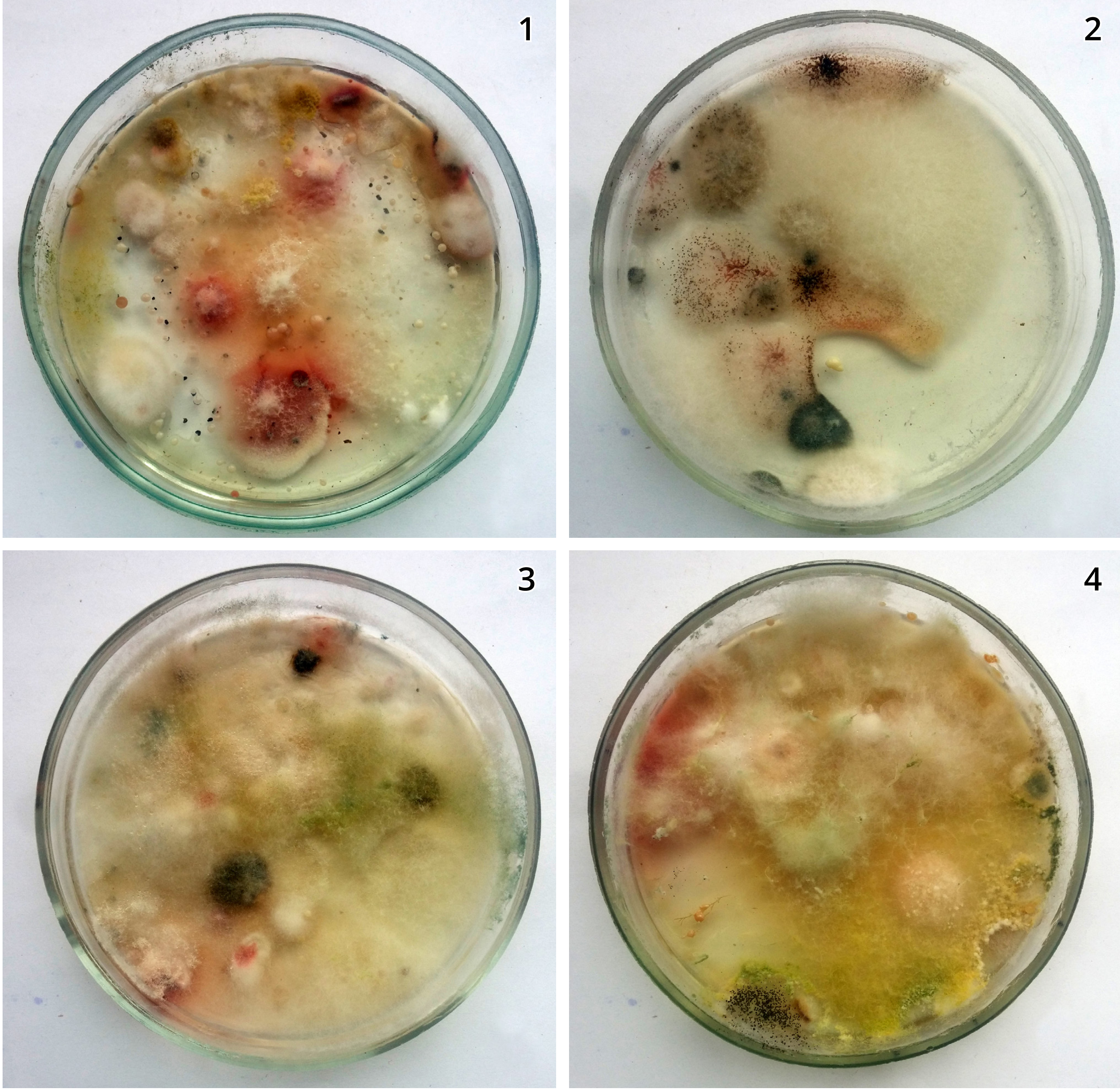

Figure 4. Diversity of micromycetes in soils under *Actinidia arguta plants*: **1** – Haplic Luvisols, Linyi (Shandong province, China); **2** – Salic Solonetz, Harbin (Heilongjiang province, China); **3** – Luvic Chernozems, Jiamusi (Heilongjiang province, China); **4** – Calcic Luvisols, NBG (Kyiv, Ukraine).

immobilizing microbiota was 1.5 times more abundant in Luvic Chernozems from Jiamusi, and 2.0 times – in Calcic Luvisols from NBG, as compared with the rest analyzed soil types.

Luvic Chernozems from Jiamusi and Calcic Luvisols from NBG exhibited the amplification of the processes of SOM mineralization. Altogether, the low values of the SOM transformation index can be the result of the input of organic matter in soils on insignificant levels.

Conclusions

The dissimilarities in the concentrations of carbon, macro- and micronutrients, phenolic allelochemicals, Eh values, and abundance of soil microbiota in the examined soil samples were shown.

The results of the analysis of variance (ANOVA) showed that the investigated factors such as pH and phytotoxicity significantly influenced the agrochemical, allelopathic and microbiological characteristics of the soils under *A. arguta* soil. pH factor affected

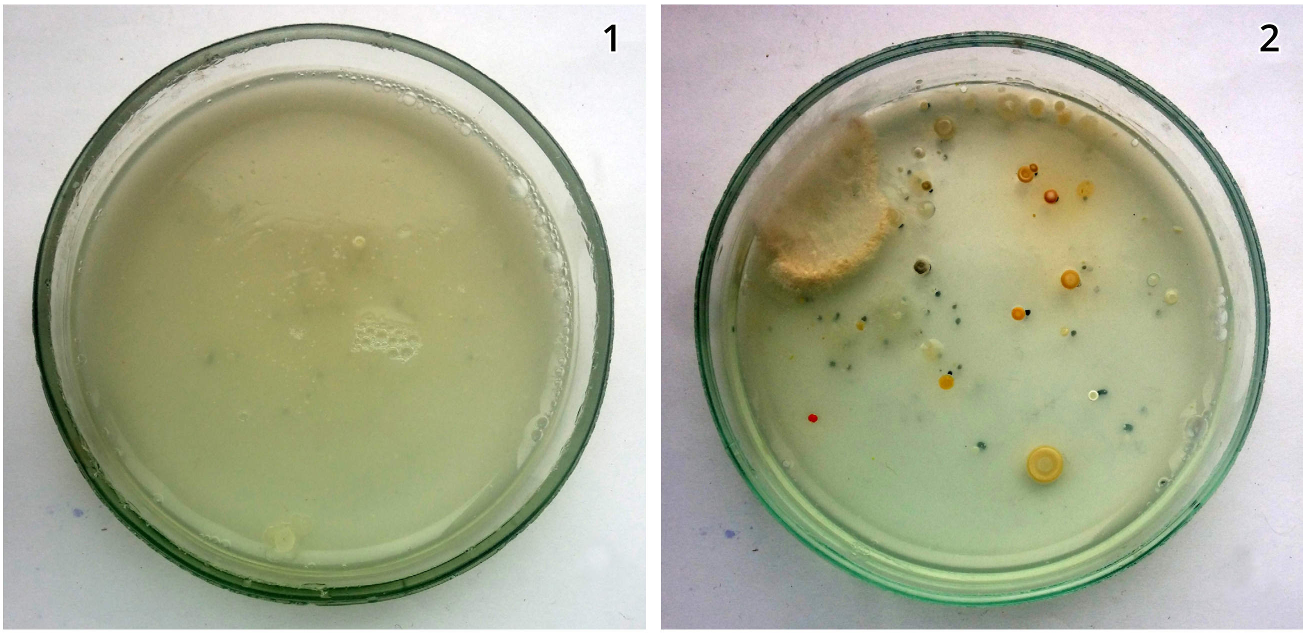

Figure 5. The abundance of actinomycetes in soils under *Actinidia arguta* plants: **1** – Haplic Luvisols, Linyi (Shandong province, China); **2** – Calcic Luvisols, NBG (Kyiv, Ukraine).

Eh, the abundance of micromycetes, the concentrations of phosphorus, iron, and manganese. Soil phytotoxicity factor showed the most potent effect on the concentrations of phenolic compounds, iron, and manganese. The relationship between the phytotoxicity and the abundance of the main taxonomical and ecotrophic groups of microbiota in soils under A. *arguta* was ascertained.

Among the analyzed soil samples, carbon concentration was the highest in Luvic Chernozems from Jiamusi and Calcic Luvisols from NBG. The reduction conditions (Eh < 400 mV) in the soils under A. *arguta* might slow down the humification processes. A similar effect may be caused by mobile forms of organic compounds with allelopathic properties. The redox potential decreased with the increase of pH values. In the soils from Harbin and Linyi, the total content of phenolic allelochemicals prevailed. Salic Solonetz from Harbin contained the lowest phosphorus concentration among the tested samples.

Meanwhile, the highest level of iron was in Luvic Chernozems from Jiamusi. In Haplic Luvisols from Linyi, the maximum concentration of manganese was observed. Low pH values increase the solubility of toxic forms of iron and manganese, which can adversely affect plant growth and development. The soil phytotoxicity under the plants of A. *arguta* reached 20-70% compared to the control. It was the lowest for Calcic Luvisols from NBG and the largest for Salic Solonetz from Harbin.

Overall, Calcic Luvisols from NBG and Luvic Chernozems from Jiamusi were determined to be the most favorable conditions for the A. *arguta* cultivation. Salic Solonetz (Harbin) and Haplic Luvisols (Linyi) were less suitable for A. *arguta* plants. Perspective is further research aimed at developing measures to improve the soil conditions for A. *arguta* plants.

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Порівняльний аналіз агрохімічних, алелопатичних та мікробіологічних особливостей ґрунтового середовища *Actinidia arguta* (Siebold et Zucc.) Planch. ex Miq. в Україні та двох провінціях Китаю

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Мета – оцінити агрохімічні, алелопатичні та мікробіологічні особливості ґрунтового середовища рослин *Actinidia arguta*, що культивуються в Україні та у двох провінціях Китаю.

Матеріал та методи. Зразки ризосферного ґрунту були відібрані на глибині 0–15 см під рослинами *A. arguta* у фазі достигання плодів в Україні (Київ: Північ України, Лісостеп, помірно континентальний клімат) та двох провінціях Китаю (Шаньдун: Схід Китаю, помірний пояс з мусонним кліматом; та Хейлунцзян: Північно-Східний Китай, континентальний мусонний клімат). Визначали концентрації вуглецю, а також доступних форм макро- і мікроелементів, фенольних сполук у ґрунтових зразках. Вимірювали pH та редокс-потенціал ґрунту. Фітотоксичність ґрунту вивчали методом прямого біотестування за приростом коренів крес-салату (*Lepidium sativum*). Проводили мікробіологічні аналізи ґрунтових зразків.

Результати. Показано відмінності у концентрації вуглецю, мікро- та макроелементів у досліджуваних ґрунтах. Панування відновних процесів (Eh < 400 mV) у ґрунті під рослинами *A. arguta* вказує на сповільнення процесу гуміфікації та наявність рухливих форм органічних сполук з алелопатичними властивостями. Зі збільшенням значень pH редокс потенціал ґрунту знижувався, що свідчить про посилення відновних процесів. Фітотоксичність ґрунту під рослинами *A. arguta* сягала 20–70 % порівняно з контролем, що, ймовірно, пов'язано із акумуляцією фенольних сполук, а також заліза та мангану. Встановлено взаємозв'язки між pH, фітотоксичністю та чисельністю основних таксономічних та еколого-трофічних груп мікроорганізмів у ґрунтах під рослинами *A. arguta*.

Висновки. Кальцієві лювісолі з Національного ботанічного саду імені М.М. Гришка НАН України (м. Київ, Україна) та чорнозем з м. Цзямуси (провінція Хейлунцзян, Китай) виявилися найбільш сприятливими для зростання *A. arguta*. Солонці з м. Харбін (провінція Хейлунцзян) та типові лювісолі з м. Ліньї (провінція Шаньдун, Китай) були найменш придатними для рослин *A. arguta*.

Ключові слова: мінеральні елементи, фенольні алелохімікати, фітотоксичність, мікроорганізми, мікроміцети, бактерії