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Aims and Scope

The aim of "Annals of Agrarian Science" is to overview problems of the following main disciplines and subjects: Agricultural and Biological Sciences, Biochemistry, Genetics and Molecular Biology, Engineering, Environmental Science. The Journal will publish research papers, review articles, book reviews and conference reports for the above mentioned subjects.

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Rare and endangered shrubs of Georgia (Caucasus) and their regional assessment according to IUCN categories and criteria

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ABSTRACT

Rare and endangered shrubs of the flora of Georgia have been evinced. Their checklist is provided below, which includes 100 species. Regional (Georgia) assessment was carried out for each species according to IUCN categories and criteria. In particular, 8 species were assessed as critically endangered (CR), 6 as endangered (EN), 11 as vulnerable (VU), and 17 as near threatened (NT). Due to the lack of data, 58 species could not be evaluated and at this stage they were assessed as data definicient (DD). Most of these species are narrow endemics of Georgia and the Caucasus. The basionyms and key synonyms of the species, the reference to taxonomy, assessment argumentation and the reference used in species assessment are given in the checklist; The endemics are marked with conditional signs.

Key words: Shrub, Taxon, Cheklist, IUCN categories and criteria, References to taxsonomy, Assessment argumentation.

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Introduction

The flora of Georgia is rich with shrub species. Approximately 280 species are distributed. Their composition is diverse. They are distributed from lowlands to alpine belt and are present in almost all ecosystems. They play a major role in maintaining the ecological balance and diversity of habitats.

The use of shrubs is versatile - food, firewood, medicine, various agricultural and household items etc. In addition, a significant part of shrubs is distributed in the grazing zones. Therefore, the shrubs are under strong anthropogenic pressure.

In order to preserve biodiversity, it is necessary to identify rare and endangered species and assess them using international norms and methods, which will allow us to develop ways of their survival and conservation in the future.

Objectives and Methods

The aim of our research was to identify the rare and endangered shrubs of the flora of Georgia and to compile their checklist; their regional assessment based on our own research and literature data according to the IUCN categories and criteria.

In addition to our own research, the second edition of "Flora of Georgia" [1-3] and the "Nomenclatural checklist of flora of Georgia" [4] laid the foundation for the creation of the checklist.

Names and authors of taxa are checked with the international databases: The Plant List (2021), Euro + Med (2006+), IPNI (2021), GBIF.org (2021), POWO (2021), Tropicos.org (2021) [5-10]. As a result, some of the "narrow" species included in the "Flora of Georgia" [1-3] and the "Nomenclatural checklist of flora of Georgia" [4] could not be

found in this checklist. These species are given as subspecies or as synonyms.

Species assessment and categorization were carried out in accordance with IUCN Red List [11] criteria. The assessment of taxa is based on our own research, literary data, results of various concluded and ongoing projects and materials preserved in various herbariums of Georgia (TBI, TGI, BATU). Some taxa are assessed based on the data from the "Red list of the endemic plants of the Caucasus" [12]. The verbal information of various researchers is also used.

Results and Analysis

100 rare and endangered shrubs of the flora of Georgia have been evinced. Their checklist is provided within the article. It is worth noting that the presented list also includes the species of woody plants, which mainly are trees and are rarely found in shrub forms.

Regional (Georgia) assessment was carried out for each species according to IUCN categories and criteria. In particular, 8 species were assessed as critically endangered (CR), 6 as endangered (EN), 11 as vulnerable (VU), and 17 as near threatened (NT). Due to the lack of data, 58 species could not be evaluated and at this stage they were assessed as data definicient (DD). Most of these species are the narrow endemics of Georgia and the Caucasus.

Below is a checklist of rare shrubs of the flora of Georgia. It includes the basionyms and key synonyms of the species, the reference to taxonomy, assessment argumentation and the reference used in species assessment. The endemics of Georgia and the Caucasus, as well as the subendemics of Caucasus are marked with the conditional signs.

Conditional signs

- – Endemic of Georgia
- - Endemic of Caucasus
- - Subendemic of Caucasus

AMARANTHACEAE (Chenopodiaceae)

Halostachys belangeriana (Moq.) Botsch. [Arthrocnemum belangerianum Moq.; Halostachys caspica (M. Bieb.) C.A. Mey.]

References to taxsonomy: [4-7];

IUCN red list category and criteria: VU D1;

<u>Assessment argumentation:</u> the number of mature individuals – <1000

<u>References used in species assessment:</u> [13-16]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI); the information provided verbally by N. Lachashvili.

Kalidium caspicum (L.) Ung.-Sternb. (Salicornia caspica L.)

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> CR B1ab (iii) + B2ab (iii);

<u>Assessment argumentation:</u> EOO – <100 km²; AOO – <100 km², area – fragmented, number of area fragments – 4, decline in habitat quality caused by grazing;

<u>References used in species assessment:</u> [13-16]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI); the information provided verbally by N. Lachashvili.

Suaeda dendroides (C.A. Mey.) Moq. (Schoberia dendroides C.A. Mey.)

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [13-17]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Suaeda microphylla Pall.

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> EN Blab (iii) + B2ab (iii);

<u>Assessment argumentation:</u> EOO – 412.108 km², AOO – 16 km², area – fragmented, number of area fragments – 4, decline in habitat quality caused by grazing;

<u>References used in species assessment:</u> [14-16, 18]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI); the information provided verbally by N. Lachashvili.

ARALIACEAE

Hedera pastuchovii Woronow

References to taxsonomy: [4-8];

IUCN red list category and criteria: NT;

Assessment argumentation: the species assessment data are approximate to VU category parameters and/or likely to be close to it in the

future;

<u>References used in species assessment:</u> [15, 19-23]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

BUXACEAE

Buxus sempervirens L. (B. colchica Pojark.)

References to taxsonomy: [5-8];

<u>IUCN red list category and criteria:</u> CR A2acde;<u>Assessment argumentation:</u> Population reduction – 95%;

<u>References used in species assessment:</u> [22-30]; B. Berdzenishvili's field data was used to assess the species (2018-2020).

CAPRIFOLIACEAE

• Sambucus tigranii Troitzky

References to taxsonomy: [4-8];

IUCN red list category and criteria: CR D;

Assessment argumentation: AOO – 12 km², area

- fragmented, number of area fragments -2,

<u>References used in species assessment:</u> [31, 32]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

CISTACEAE

Cistus creticus L.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [33]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Cistus salviifolius L.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [33]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

CORYLACEAE

Corylus avellana L.

var. pontica (K.Koch) H.J.P.Winkl. (C. pontica

K. Koch; C. imeretica Kem.-Nath.)

References to taxsonomy: [5, 7-9, 34];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [26, 35].

o Corylus colchica Albov

References to taxsonomy: [4-8];

IUCN red list category and criteria: VU B2ab (iii) *Assessment argumentation:* EOO – <20000 km²,

AOO – <2000 km²; the species is assessed based on Solomon & al., 2013 [12];

References used in species assessment: [12, 35].

ERICACEAE

Arbutus andrachne L.

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> CR B2 ab (iii, v);

<u>Assessment argumentation:</u> area – fragmented, number of area fragments – 2, decline in number of mature individuals and habitat quality caused by cutting;

References used in species assessment: [36-39].

Note: the authors of the article (N. Lachashvili, K. Kereselidze and M. Kikvidze) categorically distances from mentioning the integral part of Georgia - Abkhazia - as an independent state in the certified article (Aliev & al., 2020) and protest against the mentioned scientific journal.

• Epigaea gaultherioides (Boiss. & Balansa) Takht. (Orphanidesia gaultherioides Boiss. & Balansa)

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> VU D1;

<u>Assessment argumentation:</u> EOO - 4000 km^2 , number of area fragments -1,

<u>References used in species assessment:</u> [40]; the information provided verbally by Z. Manvelidze.

Erica arborea L.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency

of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [41].

• Rhododendron smirnowii Trautv.

References to taxsonomy: [4-8];

IUCN red list category and criteria: VU D;

<u>Assessment argumentation:</u> AOO $- <20 \text{ km}^2$, number of area fragments - 1;

References used in species assessment: [38, 42].

• Rhododendron x sochadzeae Kharadze & Daylian.

<u>References to taxsonomy:</u> [4, 5, 7, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [42].

• Rhododendron ungernii Trautv.

References to taxsonomy: [4-8];

IUCN red list category and criteria: VU D2;

<u>Assessment argumentation:</u> number of area fragments – 3;

<u>References used in species assessment:</u> [21, 38, 42, 43].

FABACEAE (Leguminosae)

o Astracantha atenica (Ivan.) Podlech

(Astragalus atenicus Ivan.)

References to taxsonomy: [5, 6];

IUCN red list category and criteria: VU D2;

<u>Assessment argumentation:</u> AOO – <20 km²; the species is assessed based on Solomon & al., 2013 [12];

<u>References used in species assessment:</u> [12, 44]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Astracantha aurea (Willd.) Podlech

(Astragalus aureus Willd.)

References to taxsonomy: [5, 6];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [45];

the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Astragalus cornutus Pall.

References to taxsonomy: [4-6];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [46, 47]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Astragalus lagopoides Lam. (A. lagurus Willd.)

References to taxsonomy: [5-8, 34];

IUCN red list category and criteria: VU D2;

Assessment argumentation: EOO – <20000 km², AOO – <20 km², number of area fragments – 1;

<u>References used in species assessment:</u> [32, 46]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

• Astragalus sommieri Freyn

References to taxsonomy: [4-5, 34];

IUCN red list category and criteria: VU D2;

<u>Assessment argumentation:</u> AOO $- <20 \text{ km}^2$, number of area fragments - 1;

<u>References used in species assessment:</u> [44]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

• Astragalus tanae Sosn.

References to taxsonomy: [4-6, 22, 23];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [22, 23, 46]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Colutea cilicica Boiss. & Balansa

References to taxsonomy: [4-8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

<u>References used in species assessment:</u> [14, 15, 48]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Eversmannia subspinosa (DC.) B. Fedtsch. [Hedysarum subspinosum DC.; Ewersmannia subspinosa (DC.) B. Fedtsch.]

References to taxsonomy: [5-8];

<u>IUCN red list category and criteria:</u> CR B2ab (iii);

<u>Assessment argumentation:</u> EOO $- <100 \text{ km}^2$, AOO $- 4 \text{ km}^2$, number of area fragments - 1, decline in habitat quality caused by grazing;

<u>References used in species assessment:</u> [14, 15, 49].

Halimodendron halodendron (Pall.) Voss (Robinis halodendron Pall.)

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: VU D2;

<u>Assessment argumentation:</u> area – fragmented, number of area fragments – 2, decline in habitat quality caused by grazing;

References used in species assessment: [17, 50-52].

FAGACEAE

• Quercus pontica K. Koch

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> VU B2ab (iii);

<u>Assessment argumentation:</u> extent of occurrence – <20000 km², area of occupancy – <2000 km², the species is assessed based on Solomon & al., 2013 [12];

<u>References used in species assessment:</u> [12, 27, 53, 54].

NITRARIACEAE

Nitraria schoberi L.

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> EN B2ab (i, ii, iii);

Assessment argumentation: EOO – 8672 km², AOO – 40 km², area – fragmented, decline in habitat quality caused by grazing;

References used in species assessment: [14-17, 55].

PLUMBAGINACEAE

Acantholimon armenum Boiss. & A. Huet

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [32, 56]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Acantholimon fominii Kusn.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [14, 15, 56]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

• Acantholimon glumaceum (Jaub. & Spach) Boiss. (Statice glumacea Jaub. & Spach)

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [32, 56];

• Acantholimon lepturoides (Jaub. & Spach)

Boiss. (Statice lepturoides Jaub. & Spach)

<u>References to taxsonomy:</u> [4-8]; <u>IUCN red list category and criteria:</u> DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [22, 23, 56].

RHAMNACEAE

o Rhamnus cordata Medw.

References to taxsonomy: [4-7];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species is assessed based on Solomon & al., 2013 [12]; <u>References used in species assessment:</u> [12, 26, 57].

• Rhamnus depressa Grubov

References to taxsonomy: [4-7];

IUCN red list category and criteria: NT;

Assessment argumentation: the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

<u>References used in species assessment:</u> [32, 57-59].

Rhamnus microcarpa Boiss.

References to taxsonomy: [4-7];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [24, 26, 32, 57, 58];

ROSACEAE

Cotoneaster melanocarpus Fisch. ex Blytt

References to taxsonomy: [4, 5, 15, 22, 23];

<u>IUCN red list category and criteria:</u> EN B1ab (iii);

<u>Assessment argumentation:</u> EOO $< 5000 \text{ km}^2$, AOO $- < 500 \text{ km}^2$, number of area fragments - 1, decline in habitat quality caused by grazing;

References used in species assessment: [15, 60].

• Cotoneaster soczavianus Pojark.

References to taxsonomy: [4, 5, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [26, 60].

Cotoneaster suavis Pojark.

References to taxsonomy: [4, 5, 7, 8, 23];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [60];

• Crataegus caucasica K. Koch

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [15, 22, 23, 32, 61].

Crataegus pseudoheterophylla Pojark.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [22, 23, 32, 61].

Cydonia oblonga Mill.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [15, 22, 23, 26, 62, 63].

Dasiphora fruticosa (L.) Rydb (Potentilla fruticosa L.)

References to taxsonomy: [4-7];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [32, 34];

o *Prunus georgica* (Desf.) Eisenman (*Amygdalus georgica* Desf.; *Prunus tenella* Batsch)

References to taxsonomy: [5, 7, 65];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

<u>References used in species assessment:</u> [17, 24, 66-69].

Prunus microcarpa C.A. Mey. [Cerasus microcarpa (C.A. Mey.) Boiss.]

References to taxsonomy: [5-8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

<u>References used in species assessment:</u> [14, 15, 17, 50, 70, 71].

• Pyrus eldarica Grossh.

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [72];

• Pyrus fedorovii Kuth.

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> EN Blab (iii, v);

<u>Assessment argumentation:</u> extent of occurrence – 529 km², area of occupancy – < 500 km², area – fragmented, number of area fragments – 4, decline in habitat quality caused by land use and grazing;

<u>References used in species assessment:</u> [22, 23, 72, 73].

• Pyrus georgica Kuth.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [15, 22, 23, 32, 73, 72].

• Pyrus ketzkhovelii Kuth.

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> CR B2ab (iii);

Assessment argumentation: extent of occurrence $-<100 \text{ km}^2$, area of occupancy $-<10 \text{km}^2$, number

of area fragments – 1, decline in habitat quality caused by land use and grazing;

References used in species assessment: [22, 23, 72, 74, 75].

• Rosa buschiana Chrshan.

References to taxsonomy: [4-8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> EOO – 1912 km², AOO – 32 km², area – fragmented, number of area fragments – 8; the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

<u>References used in species assessment:</u> [58, 59, 75-77].

• Rosa didoensis Boiss.

References to taxsonomy: [4, 5];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [58, 59, 76, 77].

o Rosa doluchanovii Manden.

References to taxsonomy: [4-8];

IUCN red list category and criteria: NT;

Assessment argumentation: AOO $- < 20 \text{ km}^2$, the species assessment data are approximate to

VU category parameters and/or likely to be close to it in the future;

References used in species assessment: [54, 75-77].

o Rosa ermanica Manden.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [76, 77]; <u>Endemism:</u> endemic of Georgia.

• Rosa galushkoi Demurova

References to taxsonomy: [4-8];

IUCN red list category and criteria: EN D;

Assessment argumentation: EOO - 0,355 km²,

number of area fragments -1;

<u>References used in species assessment:</u> [58, 59, 76, 77].

o Rosa irysthonica Manden.

References to taxsonomy: [4-7];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [76, 77].

Rosa majalis Herrm.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [77].

• Rosa marschalliana Sosn.

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future:

References used in species assessment: [58, 76, 77].

• Rosa ossethica Manden.

<u>References to taxsonomy:</u> [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [26, 76, 77].

• Rosa prilipkoana Sosn.

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

References used in species assessment: [76, 77].

Rosa rapinii Boiss. & Balansa

References to taxsonomy: [4, 5, 7, 8];

IUCN red list category and criteria: VU D2;

<u>Assessment argumentation:</u> AOO – 8 km², area – fragmented, number of area fragments – 2, decline in habitat quality, caused by land use and grazing;

References used in species assessment: [32, 75-77].

• Rosa sosnovskyana Tamamsch.

References to taxsonomy: [4, 5];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [77]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

o Rosa transcaucasica Manden.

References to taxsonomy: [4-8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

References used in species assessment: [32, 75-77].

• Rosa tuschetica Boiss.

References to taxsonomy: [4, 5, 8, 12];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> EOO – 2672 km², AOO – 40 km², area – fragmented, number of area fragments – 4, the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

References used in species assessment: [59, 75-77].

• Rosa uniflora Galushko

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [77].

o Rubus abchaziensis Sudre

References to taxsonomy: [4, 5, 7];

<u>IUCN red list category and criteria:</u> DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus adscharicus Sanadze

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [27, 78].

Rubus canescens DC.

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78];

• Rubus cartalinicus Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78];

• Rubus caucasigenus (Sudre) Juz.

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus charadzeae Sanadze

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus cyri Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus discernendus Sudre

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus dolichocarpus Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus georgicus Focke

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus ibericus Juz.

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

Assessment argumentation: data deficient

(unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [22, 23, 78].

o Rubus juzepczukii Sanadze

References to taxsonomy: [4-6, 8];

<u>IUCN red list category and criteria:</u> DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus kacheticus Sanadze

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus ketzkhovelii Sanadze

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

Assessment argumentation: data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus kudagorensis Sanadze

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus lepidulus (Sudre) Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy,

the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus leptostemon Juz.

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus longipetiolatus Sanadze

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus miszczenkoi Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus moschus Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus nakeralicus Sanadze

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in

quality of habitat etc.);

References used in species assessment: [26, 78].

o Rubus ochthodes Juz.

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus ossicus Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Rubus piceetorum Juz.

References to taxsonomy: [4-8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

o Rubus platyphylloides Sanadze

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [26, 78].

• Rubus platyphyllos K. Koch

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [26, 58, 78].

o Rubus woronowii (Sudre) Sudre (Rubus apiculatus var. woronowii Sudre)

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [78].

• Sorbus buschiana Zinserl.

References to taxsonomy: [4-5];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

<u>References used in species assessment:</u> [58, 59, 79]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

• Sorbus caucasica Zinserl.

References to taxsonomy: [4, 5, 34];

IUCN red list category and criteria: CR B2 ab (iv);

Assessment argumentation: extent of occurrence $-<100 \text{ km}^2$, area of occupancy $-<10 \text{ km}^2$, number of area fragments -1;

References used in species assessment: [26, 32, 54, 58, 75, 79].

o Sorbus fedorovii Zaik.

References to taxsonomy: [4, 5];

IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

<u>References used in species assessment:</u> [27, 54, 63, 79].

• Sorbus hajastana Gabrieljan

References to taxsonomy: [4-8];

<u>IUCN red list category and criteria:</u> CR B1ab(iii)+2ab(iii); CR D;

Assessment argumentation: extent of occurrence – <100 km², area of occupancy – 4 km², number of area fragments – 1, decline in habitat quality, caused by cutting and grazing;

<u>References used in species assessment:</u> [59]; the herbarium specimens preserved in the National Herbarium of Georgia (TBI).

Sorbus turcica **Zinserl.** [*Aria umbellata* (Desf.) Sennikov & Kurtto]

<u>References to taxsonomy:</u> [4-6, 10, 23, 34, 65]; IUCN red list category and criteria: DD;

<u>Assessment argumentation:</u> data deficient (unknown extent of occurrence, area of occupancy, the number of mature individuals and the tendency of their decline in numbers, continuing decline in quality of habitat etc.);

References used in species assessment: [79].

• Sorbus velutina (Albov) Schneid. (Sorbus aria var. velutina Albov)

References to taxsonomy: [4, 5];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

References used in species assessment: [79].

SALICACEAE

o Salix kikodseae Goerz

References to taxsonomy: [4-6, 8];

IUCN red list category and criteria: EN B1ab (iii) + 2ab (iii);

Assessment argumentation: EOO – <5000 km², AOO – <500 km²; the species is assessed based on Solomon & al., 2013 [12];

References used in species assessment: [12, 80].

• Salix kuznetzowii Laksch. ex Goerz

References to taxsonomy: [4-8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species is assessed based on Solomon & al., 2013 [12]; <u>References used in species assessment:</u> [12, 58, 59, 80].

• Salix wilhelmsiana M. Bieb.

References to taxsonomy: [4-8];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future;

<u>References used in species assessment:</u> [14, 15, 22, 23, 26, 80].

VITACEAE

Vitis sylvestris C.C.Gmell. [Vitis vinifera subsp. sylvestris (C.C.Gmel.) Hegi]

References to taxsonomy: [22, 23, 4];

IUCN red list category and criteria: NT;

<u>Assessment argumentation:</u> the species assessment data are approximate to VU category parameters and/or likely to be close to it in the future:

<u>References used in species assessment:</u> [14, 15, 22, 23, 32, 81].

Conclusion

Rare and endangered shrubs of the flora of Georgia have been evinced. Their checklist, provided in the article, includes 100 species. Regional (Georgia) assessment was carried out for each species according to IUCN categories and criteria. In particular, 8 species were assessed as critically endangered (CR), 6 as endangered (EN), 11 as vulnerable (VU), and 17 as near threatened (NT). Due to the lack of data, 58 species could not be evaluated and at this stage they were assessed as data definicient (DD). Most of these species are narrow endemics of Georgia and the Caucasus.

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Study Of Corrosion Resistance of Geopolymers Obtained On The Basis Of Local Raw Materials

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ABSTRACT

During the production of ordinary Portland cement (OPC), as a result of the decarbonization of limestone, a huge amount of greenhouse gases, mainly CO₂, are emitted into the atmosphere, which makes up about 8% of all world emissions. Consequently, any reduction in clinker use will have a serious impact on global warming. To achieve this goal, new technologies are being developed for producing clinker-free binders, one of which is geopolymers, which are considered an alternative to Portland cement.

For the widespread introduction of geopolymers into construction, it is necessary, along with other properties, to study their durability, as well as their behavior in aggressive environments, i.e., corrosion resistance.

The article is devoted to the study of the corrosion resistance of geopolymer materials obtained from local raw materials.

It was found that the indicators of corrosion resistance of geopolymer materials (changes in mass and strength) correspond to changes in their phase compositions after immersion in various aggressive solutions. In all cases, geopolymer materials showed higher resistance to aggressive solutions compared to OPC.

Key words: Geopolymers; OPC, aggressive solutions; corrosion resistance; thermally modified layey rocks.

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INTRODUCTION

Population growth worldwide increases the demand for building materials, especially for Portland cement, which remains an energy-intensive and polluting production [1, 2]. Global production of Portland cement is 4.6 billion tons per year. During the production of 1 ton of cement, 0.78 tons of CO₂ are emitted into the atmosphere by flue gases [3]. This makes cement companies one of the main producers of greenhouse gases, which account for 8% of the world's CO₂. In order to cope with the environmental crisis associated with the production of Portland cement, the trend to search for new envi-

ronmentally friendly building materials has significantly expanded over the past few decades, either by partially replacing cement with materials with pozzolan properties [4, 5], or by completely replacing cement, for example, with geopolymers [6, 7].

Geopolymers are considered environmentally friendly materials due to lower CO₂ emissions compared to analogues from Portland cement.

Using modern research methods, it has been proven that geopolymer concrete was an ancient form of concrete, which was rediscovered in the second half of the 20th century by Joseph Davidovich. He developed the concept of geopolymer-

ization and gave a new insight into this class of inorganic polymers. Davidovich developed the concept of geopolymer (Si/Al inorganic polymer) to better explain these chemical processes and the resulting material properties.

But even earlier, in the late 50s of the twentieth century, V. D. Glukhovsky [8] was the first to discover the possibility of manufacturing binders from low-base calcium or calcium-free aluminosilicates (clays) and solutions of alkali metals. He called these binders "soil cements" and "soil silicates" to reflect their similarity to natural minerals.

Fundamental research in this direction was carried out by V. D. Glukhovsky and his collaborators [9], as a result of which a new class of alkaline or alkali-activated cements (AAC) appeared. Many large infrastructure projects have been built in Ukraine using "alkaline cements" [10, 11].

A geopolymer is a material obtained by alkaline activation of aluminosilicates at ambient temperature or slightly elevated temperature, having an amorphous or semi-crystalline polymer structure with Si⁴⁺ and Al³⁺ cations, tetrahedrally coordinated and linked oxygen bridges [1, 2]. During hydration, geopolymers give a product that is predominantly calcium silicate hydrate.

Geopolymers have a number of properties compared to Portland cement: high compressive and flexural strength, low shrinkage, low permeability; high resistance to fire and aggressive environments. Due to these properties, geopolymers can be used in many areas: ceramics [12], concrete [13], insulation [14], stabilization and sorption of hazardous waste [15], etc. They depend on many factors, including nature and chemical mineralogical composition of raw materials.

Despite the fact that the processes of structure formation of geopolymer and other binders have not been studied well enough, these binders are considered as a promising resource-saving alternative to Portland cement. Studies have shown that a significant advantage of geopolymers is their high strength, density, water resistance, heat and heat resistance, and corrosion resistance [16-18]. However, today, the advantage of using these materials is only the possibility of using a huge amount of accumulated industrial waste all over the world.

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For the widespread introduction of geopolymers in construction, it is necessary, along with other properties, to study their durability, as well as their behavior in aggressive environments, i.e., corrosion resistance.

Sulfate and chloride corrosion of building materials is one of the most significant types of corrosion. It manifests itself when building structures are exposed to saline sea and ground waters, atmospheric air with an increased content of sulfur compounds, as well as acid rain [18].

Geopolymer concrete based on low-calcium fly ash has, according to [19], high sulfate resistance. Samples exposed to sodium sulfate solution for one year showed no visible signs of surface deterioration, cracking, or flaking. The compressive strength values remained the same as before the samples were immersed in an aggressive environment.

According to [20, 21], the leading cause of the destruction of reinforced concrete structures is the destruction under the action of carbonation and chloride ions that cause corrosion of reinforcement. They do not directly affect concrete and contribute to the corrosion of reinforcement in concrete. Atmospheric carbon dioxide reacts with calcium hydroxide, causing a decrease in pH in the pore space. As a result, the protective properties of concrete in relation to reinforcing steel are reduced. Chloride ions can penetrate into concrete through aggregate, mixing water or accelerating additives. However, in practice this rarely happens due to strict restrictions on the content of chlorides in concrete. As a rule, chlorides penetrate concrete from the outside, or from seawater, as well as due to the use of de-icing salts. Carbon dioxide and chlorine compounds, as well as other aggressive substances can cause the destruction of concrete only in the presence of water.

The mechanism of chloride penetration and diffusion of CO2 from the environment together with the movement of water in concrete plays an important role in the destruction of concrete. These phenomena are the key factors that determine the durability of concrete based on Portland cement and geopolymer concrete.

As many researchers note, geopolymers have less acid resistance than sulfate resistance: the maximum decrease in the characteristics of geopolymer materials after 1 year of holding samples in a 2% solution of sulfuric acid did not exceed 3%, which was quite insignificant compared to the complete destruction of control samples based on Portland cement [19]. The degree of damage associated with acid exposure is directly proportional to the concentration of acid in the immersion solution.

For a number of years, we have carried out research on the production of geopolymer materials using local raw materials. Technologies have been developed for obtaining geopolymer materials using thermally modified clay rocks of Georgia, on the basis of which geopolymer materials of various compositions have been synthesized [22, 23, 24].

This article presents the results of studies of the corrosion resistance of these materials.

EXPERIMENTAL PART

2.1. Materials

For the study, a geopolymer materials was used, made on the basis of clay rocks of Georgia (argillite and low-melting clay) modified at 700 °C and granulated blast-furnace slag of the Rustavi Metallurgical Plant.

An alkaline activator NaOH, Na₂CO₃, and Na₂SiO₃ was used as a mixing liquid.

2.2. Methods

A NETZSCH derivatograph with STA-2500 REGULUS thermogravimetric and differential thermal analyzer (TG / DTA) was used for thermogravimetric analysis. Samples were heated to 1000 °C, in a ceramic crucible, heating rate 10 °C / min. Reference substance α -Al₂O₃.

The X-ray phase analysis was carried out using

a Dron-4.0 diffractometer ("Burevestnik", St. Petersburg, Russia) with a Cu-anode and a Ni-filter. U=35kv. I=20mA. Intensity - 2 degrees / min. λ = 1.54178 Å.

2.3. Geopolymers preparation

Temperature modification of argillite and clay was carried out by heating the material in a muffle furnace to a temperature of 700 ° C with exposure at a maximum temperature of 1 hour.

Geopolymer materials were prepared as follows: granulated blast-furnace slag and modified argillite or clay in a ratio of 80:20, were ground together in a laboratory ball mill to a specific surface area of 8000-10000 g/cm². Dry substances were added to the resulting powder in a certain amount: NaOH or Na₂CO₂, or Na₂SiO₂, or their mixture, which were mixed well for 5 minutes. Water was added to the dry mixture to obtain a dough of normal consistency. Samples were molded with a size of 2 x 2 x 2 cm. The molds, together with the samples, were wrapped in a plastic film to prevent the binder from drying out and were immediately placed in a heat treatment chamber. Heat treatment of geopolymer materials was carried out at 80°C for 24 hours. The samples were randomly cooled in the chamber until they reached room temperature.

In order to test for corrosion resistance, geopolymer materials were immersed in aggressive solutions: $\rm H_2SO4$ (concentration 2% and 5%), HCl (concentration 2% and 5%) and $\rm Na_2SO_4$ (concentration 5%).

RESULTS AND DISCUSSION

Table 1 shows the chemical compositions of clay rocks: argillite from the Teleti deposit (No.1) and clay from the Gardabani deposit (No.2).

Table 1. The chemical composition of clay rocks, mass. %

No.	LOI	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	Mn ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O
1	7.01	47.19	15.90	13.36	0.10	6.30	4.10	1.39	2.86	1.30
2	10.60	52.84	15.07	6.47	-	7.06	2.49	1.36	1.19	2.17

In Fig. 1 shows X-ray patterns of the studied clay rocks where the presence of clay minerals is recorded (14.66 - 14.96, 7.14, 4.25, 3.66, 2.86,

2.327 Å); quartz (3.34 Å); feldspar (3.87 Å), calcite (3.03 Å).

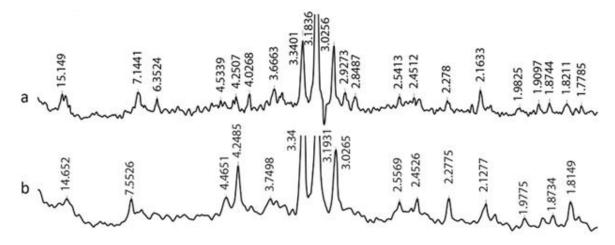


Fig. 1. X-ray patterns of clay rocks: a - argillite, b - clay

According to the data of differential thermal analysis (Fig. 2), the endo-effect at 100–150°C is present on all DTG curves, which corresponds to the removal of physically bound water. In the temperature range of 650–850°C, an endo-effect is observed, which is obviously connected with the

destruction of the crystal lattice of clay minerals and their transition to the active amorphous form (metakaolin). On this basis, the temperature of 700°C was chosen for the thermal treatment of clayey rocks.

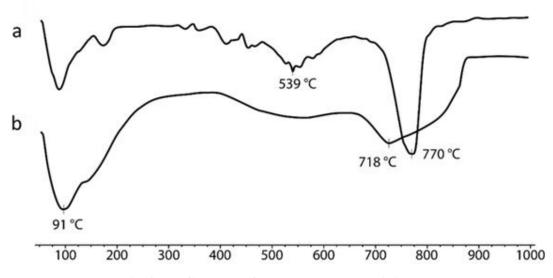


Fig. 2. DTG curves of clayey rocks: a- argillite, b - clay

The assessment of the corrosion resistance of geopolymer materials was carried out according to the change in the mass and strength of the samples after 180 days their immersion in aggressive solutions, which were 2% and 5% solutions of H₂SO₄ and HCl, as well as a 5% solution of Na₂SO₄.

For the purpose of comparison, Ordinary Portland Cement (OPC) was tested, sealed with ordinary water, which was immersed in the same aggressive solutions.

As shown by the test results (Table 2), geopolymer materials have a higher acid resistance and sulfate resistance compared to OPC, which is in good agreement with the data of other studies [25, 26]. According to the authors of [27], the high corrosion resistance of geopolymer materials is explained by the absence of Ca(OH)₂ in their composition, a compound that is the main cause of the destruction of Portland cement concrete.

Composition No.**27 showed lower results in corrosion resistance, which is obviously due to the fact that this composition was not subjected to heat treatment. It is known that the heat treatment of geopolymers accelerates the processes of polymerization and pozzolanization [28, 29], which increases their resistance to aggressive solutions.

Compositions No.6 and No. 7 were also characterized by lower mechanical strength and corrosion resistance, since they do not include a

clay component - a source of metakaolin, which provides the geopolymer structure with a high degree of polymerization.

Table 2. Compositions of geopolymer materials and the results of their corrosion resistance

No	Composition of the geopolymer, (%)		Alkaline activator	Weight loss of samples (%) after 180 days immersion in solution				Strength	Loss of strength of samples (%) after 180 days immersion in solution					
140.			composition,	H ₂ SO ₄		HCl		Na ₂ SO ₄	before testing, MPa	H ₂ SO ₄		HC1		Na ₂ SO ₄
			(%)	2%	5%	2%	5%	5%	testing, wir a	2%	5%	2%	5%	5%
*11	Slag	Clay	NaOH (4) +	1.49	2.17	2.67	4.77	0.62	97.5	6	8	9	11	1.8
	80	20	Na ₂ SiO ₃ (10)											1.8
*27	Slag (80)	Argillite (20)	NaOH (4) + Na ₂ SiO ₃ (10)	0.25	1.32	0.15	3.91	0.63	92.5	7	11	10	15	1.9
**27	Slag (80)	Argillite (20)	NaOH (4) + Na ₂ SiO ₃ (10)	7.34	9.50	4.53	12.9	0.64	65.0	12	25	17	29	2.6
*15	Slag (80)	Argillite (20)	Na ₂ CO ₃ (15)	1.15	2.49	1.72	5.5	0.22	88.0	7	12	11	17	1.5
*25	Slag	Argillite	Na ₂ CO ₃	1.38	2.92	0.75	5.88	0.87	82.0	8	11	10	17	2.1
23	(80) (20) (7)	(7)	1.50	2.92	0.75	3.00	0.67	82.0	0	11	10	17	2.1	
*6	Slag (100)	-	Na ₂ SiO ₃ (10)	4.53	6.97	5.34	9.94	2.29	77.0	15	26	24	37	3.3
*7	Slag (100)	-	NaOH (4) + Na ₂ SiO ₃ (10)	5.81	9.18	3.22	9.06	2.53	75.0	19	23	22	31	4.2
C	Ordinary Portland Cement (OPC)			18.11	***	27.7	***	32.8	73.0	62	***	70	***	80

^{*}Curing mode: heat treatment at 80 ° C for 24 hours.

According to the authors [27, 30], the corrosion resistance of geopolymer materials is also due to the fact that there are no high-base calcium hydroaluminates in their hardening products that cause sulfate corrosion, and there is also no free lime, leaching of which occurs in soft waters. Therefore, geopolymer concretes are superior in corrosion resistance even to sulphate-resistant concretes based on Portland cement.

According to [26], if metakaolin is mixed with a certain amount of NaOH solution or NaOH + Na₂SiO₃ solution, and then cured at temperatures below 100° C, it is possible to obtain a solid substance having a lattice structure of aluminosilicate resembling a zeolite material having high mechanical strength. This is what happens when geopolymers are hardened according to the curing mode: heat treatment at 80 °C for 24 hours (Table 2 - compositions Ne*11, *27, *15, *25).

For X-ray phase analysis composition No.*27 was chosen, which was synthesized from 80% slag and 20% argillite (Table 2) and activated with a solution of NaOH + Na₂SiO₃.

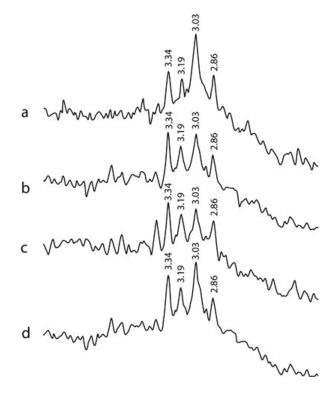


Fig. 3. X-ray patterns of sample No. *27: a - before immersion in an aggressive solution; b - after 180 days of immersion in 5% H2SO4 solution; c - after 180 days of immersion in 5% HCl solution; dafter 180 days of immersion in 5% Na2SO4 solution

^{**} Curing mode: in air at 20 $^{\circ}$ C for 28 days.

^{***} Samples collapsed.

The X-ray diffraction patterns of the geopolymer material show a certain process. The main phases of the material before its immersion in an aggressive solution (Fig. 3a) are: X-ray amorphous phase and diffraction lines of quartz (3.33 Å), feldspar (3.19 Å), calcite (3.03 Å) and slag (2.86 Å).

After 180 days immersing of the material in a 5% H₂SO₄ solution (Fig. 3b), the phase composition remains the same, but the amount of the X-ray amorphous phase decreases, as does the intensity of the diffraction lines of calcite (3.03 Å). The same picture is observed after immersion of the material in a 5% HCl solution: a decrease in the amount of the X-ray amorphous phase and calcite (Fig. 3c).

As the authors of [31] believe, the main reason for the loss of concrete strength in an acid solution is the degradation of the geopolymer matrix, which is reflected in a decrease in the intensity of the X-ray amorphous phase in X-ray patterns 3b and 3c.

Another process is observed when the material is immersed in a 5% Na₂SO₄ solution (Fig. 3d). Here, the phase composition and phase ratios remain almost on par with the initial material.

So, as our studies have shown, geopolymers obtained from local raw materials have a high resistance to aggressive solutions, which is in good agreement with the data of other researchers whom we have cited.

Geopolymers are environmentally friendly materials, and the technology for their production belongs to green technologies.

If geopolymer materials displace, or at least reduce the production of OPC, this will allow to obtain resource-saving and environmental effects by replacing carbonate raw materials, which during firing loses almost half of its mass when emitting carbon dioxide polluting the environment.

CONCLUSIONS

Corrosion resistance of geopolymer materials obtained on the basis of local raw materials depends on the composition of the aggressive solution:

- 1. The higher the concentration of the aggressive solution, the greater the loss of weight and strength.
- 2. Geopolymer materials are less stable in HCl solutions than in H₂SO₄, and rather stable in Na₂SO₄ solution.

The indicators of corrosion resistance of geopolymer materials (change in mass and strength) after immersion in various aggressive solutions

correspond to changes in their phase compositions.

The corrosion resistance of geopolymer materials is always higher than the OPC under equal conditions of aggression.

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Comparative effectiveness of different types of aggregate pheromone traps for monitoring Brown marmorated stink bug - Halyomorpha halys (Stål) (Insecta: Hemiptera: Pentatomidae)

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ABSTRACT

The discovery of the aggregation pheromone has allowed researchers to design lures which attract the brown marmorated stink bug to the vicinity of the lure types location. For the monitoring three type of traps were Used, 1 – sticky-panel trap, 2 – Rescue trap (Sterling International), 3- Handmade trap constructed by using 1.5 liters plastic bottles. The first individuals of *H.halys* on all three types of traps were observed in April. The presence of the highest number of individuals (adults + nymphs) was observed in the June on the sticky trap. Each month, the number of captured *H.halys* by each type of trap differed significantly from each other (Chi-square - 81.09, df-46, P-value < 0.0011). Also, a significant statistical difference was observed in terms of *H.halys* caught by all three traps during the season (Chi-square - 69.14, df-12, P-value < 0.0001). There was also a significant statistical difference between the proportion of adults and nymphs in the captured insects. In particular, in April, May and October, the presence of nymphs was not observed in the traps at all, while more nymphs were observed in July and August . In this case, the sticky trap proved to be the most effective, in June, July, August and September, an average of 22, 45, 37, 14 nymphs were observed on the sticky trap, the rescue trap caught 5, 16, 19, 0, and the handmade trap caught 3, 14, 13, 0 (n=3) accordingly.

Key words: Brown marmorated stink bug (BMSB), aggregation pheromone, traps, monitoring.

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Introduction

The brown marmorated stink bug (BMSB), Halyomorpha halys, is an invasive pentatomid, native to East Asia and spread throughout of the US, Canada, as well as into Europe and become a severe invasive agricultural pest.

BMSB is a highly polyphagous, has a broad host range that includes over 170 plants, many of agricultural importance, including fruit, vegetables, row crops, and ornamentals. It is also a structural pest, with high reproductive output, potentially enabling its spread and success in invaded regions, as large populations invade houses, trying to

overwinter. BMSB is capable of long-distance flight [1,2].

Following its first detection 2015, *H. halys* has become a key pest in many crops in West Georgia [3-5] Therefore it is grate possibility, that invasion pest as favored by prolific reproduction, wide host range, lack of specific natural enemies, cold tolerance, global warming, and overwintering skills likely increase and spread in all territory of Georgia [6].

At present BMSB is very active and characterized by the massive increase and formation of focuses in the large tracts of agrocenosies and urban area of Georgia. Management using ecological friendly tools is a promising approach. Natural enemies, biopesticides, special techniques such as banding trees, using aggregation pheromones can reduce amount of pesticide applied. The brown marmorated stink bug is not going to go away, but IPM techniques can limit the damage.

Novoday the situation is quite alarming in Western Georgia (Guria, Adjaria, Abkhazia, Samegrelo-Zemo Svaneti, Imereti, Racha, Lechkhumi,). To date, sustainable control strategies against BMSB is very actual. The development of ecological friendly management strategies against BMSB-*H. halys*, are urgently needed to preserve biodiversity of Georgia.

In recent years, usage of the control method, called mating disruption, for the monitoring studies and control is highly encouraged. Various countries use artificial semi chemicals – pheromones – against many pests insects, including BMSB [7-9]. Using eco-friendly means will help preserve biodiversity and promote ecological balance.

The aim of the study is to develop of ecological friendly management strategies against BMSB-*H. halys* using biotechnological methods.

Material and Methods

Pheromon trap

The determation of the population densities of the *H. halyes* 2020, trap system, with pheromone *Halyomorpha halys* PH-611-1BPD (Russell IPM Ltd Company) (Ethyl (E, Z, Z)-2,4,6-decatrienoate, murgantiol) were installed. A long-term trapping was conducted at hazelnut orchard in Samegrelo region, of Western Georgia. 9 pheromone traps

were set up on the 1 hectare (ha). Traps and lures were placed within crops about 2 meters above ground. Captured insects were removed on each sampling occasion which makes counting new arrivals easier. Lures was changed every 10 -12 weeks to get the most accurate results.

For the experiments three type of traps were Used, 1 – sticky-panel trap, 2 – Rescue trap (Sterling International), 3- Handmade trap constructed by using 1.5 liters plastic bottles which was filed 250 ml water. To observe *H. halys* movements Camera Yoosee Wireless 1080P were set up, connected to phone and checked daily.

Statistical Analysis

The total numbers of insects responding to the pheromones were analyzed with a Fisher's exact Chi-square test by using GraphPad Prism to determine if the distribution of the insects differed for the trap types and months as well. ANOVA analysis was performed to estimate the proportion of nymphs and adults in captured insects.

Results

Experimental data showed that as the first individuals of *H.halys* on all three types of traps were observed in April. The presence of the highest number of individuals (adults + nymphs) was observed in the June on the sticky trap. Each month, the number of *H.halys* captured by each type of trap (Fig.1) differed significantly from each other (Chi-square - 81.09, df-46, P-value < 0.0011) (Fig.2.).



Fig. 1. Three type of traps: 1 - sticky trap, 2 - Rescue trap (Sterling International), 3 - Handmade trap

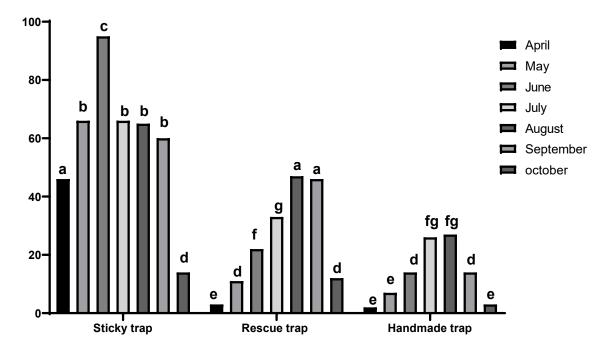


Fig. 2. (Seasonal response of H. halys adults and nymphs to different trap styles). Total numbers of H. halys captured by three different traps according months. Bars with different letters are significantly different (P<0.05).

Also, a significant statistical difference was observed in terms of *H.halys* captured by all three

traps during the season (Chi-square - 69.14, df-12, P-value <0.0001) (Fig. 3, Table 1).

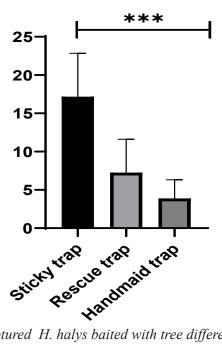


Fig. 3. The total number of captured H. halys baited with tree different trap type

There was also a significant statistical difference between the proportion of adults and nymphs in the captured insects (Table 2.). In particular, in April, May and October, the presence of nymphs was not observed in the traps at all, while more nymphs were observed in July and August (Fig. 4). In this case, the sticky trap proved to be the most effective, in June, July, August and September, an average of 22, 45, 37, 14 nymphs were observed on the sticky trap, the rescue trap caught 5, 16, 19, 0, and the handmade trap caught 3, 14, 13, 0 (n=3) accordingly.

Table 1. Tukey's multiple comparisons between total numbers of captured H. halys

	Mean Diff,	95,00% CI of diff,	Significant?	Summary	Adjusted P Value
Sticky trap vs. Rescue trap	9,917	6,899 to 12,93	Yes	****	<0,0001
Sticky trap vs. Handmaid trap	13,29	10,27 to 16,31	Yes	****	<0,0001
Rescue trap vs. Handmaid trap	3,375	0,3570 to 6,393	Yes	*	0,0247

Table 2. Comparative analysis among adults and nymphs captured by using different trap style

	Sticky tra	ар	Rescue trap		Handmade trap		
	Adult	Nymph	Adult	Nymph	Adult	Nymph	
Mean±SE	42±8,4	16,9±7,1	19,1 ± 5,3	5,7 ± 3,1	9,4±2,1	4,1±2.3	
Confidence Level (95,0%)	20,6	17,2	13,0	7,7	5,0	5,7	

^{*}ANOVA single factor, P value - 0,000125, df-5

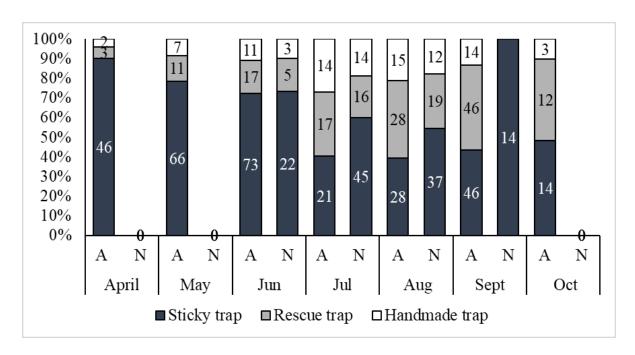


Fig. 4. Proportion of captured adults and nymphs by different trapping style according months

Discussion

The discovery of the aggregation pheromone has allowed researchers to design lures which attract the brown marmorated stink bug to the vicinity of the lure location. When combined with traps, including black pyramid traps and sticky traps, the lures can allow growers to determine when stink bug populations are at levels that warrant pesticide applications [10]. Additionally, an attract-and-kill approach is under development, which aims to use the pheromone lure to attract stink bugs to specific trees which are then sprayed with pesticides [11].

The effect of trapping locations is clearly an

important factor that may restrict interpretations of stink bug phenology [12]. To address this, research that monitors endemic stink bug populations in and around production systems (rather than invasive species around transitional facilities) will help to validate the findings presented here. Trap placement within the canopy significantly affects BMSB catch [13] and other placement factors (e.g. in orchard versus in hedgerows, or within native versus non-native hosts) may be similarly important. Additionally, the lures used in this study attracted a broad range of stink bugs, but are unlikely to attract other species evenly [14, 15].

The pheromone-based tools developed for H. halys may beemployed for monitoring of the species. In the development of commercially viable lures, there are several important considerations. For example, unlike many species of Lepidoptera where highly purified pheromone is needed [10], H. halys does not require highly purified pheromone; other stereoisomers of 10,11-epoxy-1-bisabolen-3-ol (murgantiol) do not elicitinhibition of response, and the species is even possibly attracted to stereoisomers not naturally found in the wild [16]. This suggests that impure blends of the main pheromonal components may be used without impairment of biological activity. In addition, there is adose-dependent response in attraction to both the aggregation pheromone [11] and EEZ-MDT [17], such that more pheromone results ingreater number of adults and nymphs captured. Finally, it is important that a lure be long-lasting so that it requires little maintenance during the growing season. The original rubber septa lures used with H. halys pheromone for research purposes required changing every 2 weeks, where as currently available commercially formulated lures with the H. halys aggregation pheromone recommend changing once every 4 weeks (AgBio, Inc.) or once every12 weeks (Tre'ce', Inc), and a lure may be for thy coming in the near future that will remain attractive over the entiregrowing season for 16 weeks (Short and Leskey, unpublished data). Prior work has demonstrated that commercially available EEZ-MDT lures last a maximum of four weeks [18]. Commercially availablelures have demonstrated season-long attraction of H. halys throughout the USA when changed regularly [15], as well as in the species' native range in the Republic of Korea [19, 20].

Conclusion

The discovery of the aggregation pheromone has allowed researchers to design lures which attract the brown marmorated stink bug to the vicinity of the lure types location. The results obtained revealed that, Rescue *Halyomorpha halys* PH-611-1BPD pheromones lures are very effective types of traps for monitoring *H.halys* population. Overall, our results suggest that *H. halys* monitoring traps can be further improved to reduce cost and labor associated with deployment and maintenance.

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Biosynthesis of silver nanoparticles using water extracts of Nepeta cataria L. and Salvia sclarea L., characterization and determination of antibacterial potential

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ABSTRACT

Benefits of silver nanoparticles (AgNPs) against various pathogens and their other benefits are already well known in medicine. Meanwhile, applications involving nanotechnology have the potential to aid agricultural production. Bacteria, fungi, viruses that cause plant diseases can be controlled with AgNPs. Bacterial infections cause significant loss of yield around the world. AgNPs have shown activity against plant pathogenic bacteria. They have higher antibacterial activity against erwinia cartovora, E. than antibiotics. AgNPs also lave antifungal activity against pathogenic fungi, ie. Fusarium oxysporum, Alternaria Alternaria and Aspergillus flavus. They represent alternative to pesticides, are able to protect plant from pest and enrich soil with nutriants. Their use may reduce demand on chemical fertilizers. It is already used as foliar spray against moulds, rot, fungi and other microbial associated plant diseases . AgNPs can benefit preservation process of food. Their addition to food packaging can improve their barrier, mechanical, and antibacterial properties, and maintain the quality of foods. Biosynthesis is simple, effective, environmentally friendly and inexpensive way for production of silver nanoparticles. Process does not require high temperature and pressure. It is characterized by low energy costs. In given study silver nanoparticles were biosynthesized using water extracts of *Nepeta Cataria L*. (Catnip) and *Salvia Sclarea L*, (Clary sage). Process of biosynthesis was observed and optimal conditions were determined. Morphology of obtained nanoparticles was investigated using TEM method and AgNPS were evaluated for antibacterial activity against ten stains of Gram-negative and Gram-positive bacteria.

Key words: Nepeta cataria L., Salvia sclarea L., antibacterial potentional

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Introduction

Nanotechnology is a new field of scientific research that has been very well known over the last few decades [1]. It has a wide range of uses in microbiology and biotechnology. It is useful for developing, designing, and manipulating nanostructures with very small dimensions and a large surface area-to-volume ratio. Nanoparticles are attracting the attention of researchers in various fields due to their extraordinary properties. The morphology, size, and chemistry of nanoparticles are used to classify nanoparticles and are therefore

classified according to their physical and chemical properties. There are several known classes of nanoparticles, including organic, inorganic, and carbon-based [2].

A bulk material has constant physical properties regardless of their size and shape, but at the nanoscale, the size, morphological substructure of the substance, and shape are the major driving factors for changing their biological, chemical, and physical properties. Because at the nanoscale, the materials behave differently and they emerge with few novel characters in themselves [3].

Metal nanoparticles have size-related properties

that are significantly different from bulk materials. These unique properties are ambassadors for potential applications in medicine, catalysis, optics, cosmetics, renewable energy, microelectronics, medical imaging, environmental restoration, and biomedical equipment [4]. Of the wide range of metal nanoparticles, silver nanoparticles (AgNPs) are the most popular due to their unique physical, chemical, and biological properties when compared to their macro-scale equivalents [5].

The effect of silver nanoparticles against various pathogens and other benefits are already well known in medicine. AgNPs can be used in medicine for antimicrobial and antitumor therapy [6]. They exhibit antiviral effect and they were found to be able to combat even SARS-CoV-2 virus [7, 8]. Meanwhile, applications involving nanotechnology have the potential to aid agricultural production. It has already begun to have a significant effect in the main areas of the agriculture and development towards this way continues. Many findings have been made regarding them in agriculture and interest has risen lately. Various bacteria, fungal, viral species can cause plant diseases [9]. While their management is not an easy task AgNPs can be useful to combat microorganisms causing them. Bacterial infections cause significant loss of yield around the world. AgNPs have shown to be active against plant pathogenic bacteria. Research showed that AgNPs have higher antibacterial activity against erwinia cartovora, E. than antibiotics [10]. Antifungal activity of AgNPs was also studied against pathogenic fungi, ie. Fusarium oxysporum, Alternaria Alternaria and Aspergillus flavus [11]. Silver nanoparticles proved themselves as attractive alternative to pesticides. They are able to protect plant from pest and enrich soil with nutriants. Thus, use of chemical fertilizers can be reduced. It is already used as foliar spray against moulds, rot, fungi and other microbial associated plant diseases [12]. AgNPs have good potential for increasing crop yields by promoting seed germination and plant growth, though it has to be mentioned that effect can be also negative [13], but besides, it can benefit preservation process of food which is important in agriculture. The addition of AgNPs into food packaging can improve their barrier, mechanical, and antibacterial properties, as well as maintain the quality of foods [14].

Several main methods are available for obtaining silver nanoparticle, though currently most interesting, promising for synthesis of silver nanoparticles is so-called green synthesis. Scientists

working in this field focuse on the development of efficient and environmentally friendly methods for synthesizing metal nanoparticles using green chemistry. Emerging interest is caused by several reasons. Biosynthesis of silver nanoparticles has significant advantages over chemical and physical methods [15]. Biosynthesis is simple, effective, environmentally friendly and inexpensive way for production of silver nanoparticles [16]. Process does not require high temperature and pressure. It is characterized by low energy costs [17]. Process involves use of biological resources which serve as reducing, stabilizing and capping agent at the same time. Method enables us to obtain relatively safe AgNPs, as the surface of nanoparticles contains little or no toxic materials. Very important finding is that nanoparticles obtained through biosynthesis are primarily biocompatible and can be used for biomedical applications [18,19]. In the scientific literature, biosynthesis of silver nanoparticles is described using plants, bacteria, [20] fungi [21], algae [22] and even with honey [23]. Green synthesis of silver nanoparticles using plant extracts is the most attractive out of listed above. Plants contain various compounds that serve as the reducing agent of metal cations including silver [24].

In given study silver nanoparticles were biosynthesized using water extracts of *Nepeta Cataria L*. (Catnip) and *Salvia Sclarea L*, (Clary sage). Obtained nanoparticles were evaluated for antibacterial activity against ten stains of Gramnegative and Gram-positive bacteria.

Objectives and Methods

Plant extracts used for biosynthesis of silver nanoparticles

The shoots of the raw plants were used to prepare the plant extract. Plant material was washed with distilled water. After drying, they were cut into 2 cm long pieces. To obtain the extract, 35 g of each finely chopped raw material were placed in a beaker. 400 ml of distilled water was added to each of them. Beakers were later placed in a Hyundai microwave for 10 minutes. The mass was heated by the dielectric heat and then was left cool down at room temperature for one hour. On the next step the mass was drained onto cotton to remove the finely chopped plant waste. Finally, to obtain the extract, the liquid was filtered into the filter paper produced by MELIOR XXI Ltd. (ashless filter d = 150 mm).

Biosynthesis of Silver Nanoparticles

For biosynthesis pre-prepared extracts and 0.1N solution of silver nitrate were used. A series of samples with different ratios of AgNO3 and extracts were prepared to determine the optimal conditions for the silver nanoparticle biosynthesis process. To determine the effect of temperature on the reaction, part of the samples were kept at a room temperature and the rest in the refrigerator. The influence of the pH on the process was also observed. Measurements were performed using pH meter, firstly of water extracts and afterwards when the silver nitrate was added to the extract. Later the pH of the reaction mixture was changed using 20% NaOH solution. The biosynthesis process was observed in time dependent manner. After mixing the plant extract and silver nitrate solution in 1, 24 and 48 hour intervals samples were photographed to detect visually noticeable changes.

UV-Vis spectroscopy

In order to prove and evaluate formation of silver nanoparticles in the prepared solutions, UV-Vis spectroscopy was performed after 1, 24 and 48 hour intervals. The research was conducted on the i9 UV-VIS spectrophotometer (Hanon Instruments) owned by the Department of Pharmaceutical Technology of Tbilisi State Medical University. This method is used to detect plasmon resonance characteristic for silver nanoparticles [5]. Mostly silver nanoparticles have absorption peak in the range of 400-450 nm. In present case the absorption spectrum was recorded in the range of 330-800 nm.

Transmission electron microscopy - TEM

TEM microscopy was used to determine the size of formed silver nanoparticles and to study their morphology and distribution. Microscopy was performed at the George Eliava Institute of Bacteriophage, Microbiology and Virology using a JEOL JEM-100SX transmitting electron microscope. Samples were prepared according to regime required by TEM analysis, negatives were taken, and finally the exposed images were obtained at 120,000 magnification. Particle sizes were measured following it.

Antibacterial activity assay

The study of antibacterial activity was performed at the Giorgi Eliava Institute of Bacteriophage, Microbiology and Virology. The study of the antibacterial activity of biosynthesized silver nanoparticles was conducted using so-called Spot Test method on the following strains: Klebsiella spp, E-coli, Pseudomonas aeruginosa, Streptococcus spp, Enterococcus spp, Shigella spp, Salmonella spp, Enterobacter spp, Proteus spp, Staphylococcus aureus. For this on a petri dish containing 2% BH agar bacterial lawns were formed: 1 ml of bacterial culture was applied and distributed over the entire cup. 10 µl test objects were applied after drying. Plates were placed in a thermostat for 18-24 h incubation. Solutions of biosynthesized silver nanoparticles from both catnip (N1) and clary (N2) represented research objects, but for control antibacterial activity of blank extracts were also determined in order to evaluate action in relative aspect (Nepeta Cataria L. extract N3, Salvia sclarea L. N4)

Results and Analysis

Obtained UV-vis absorption spectra proves formation of silver nanoparticles. The absorption measure increased with time, indicating enhanced plasmonic resonance which on its side is a sign that number of formed nanoparticles increased as time passed. For silver nanoparticles biosynthesized with Catnip extract, the peak of absorption after one hour was observed at 460 nm and reached 0.7. After 24 hours, the peak on the spectrum was recorded at 462 nm and reached 1.0. And after 48 hours the peak was observed again at 462 nm, the absorption maximum increased to 1.3. In case of silver nanoparticles biosynthesized with Clary sage extract, the peak of absorption after one hour was observed at 484 nm and reached 1.6. After 24 hours, the peak on the spectrum was recorded at 488 nm and reached 2.2. And after 48 hours the peak was observed again at 504 nm with absorption maximum 2.5. (Fig.1). According to the literature we have reviewed, the change in wavelength is due to the clustering of particles and the change in size [2]. The ongoing process of biosynthesis was reflected by a change in the color intensity of the study objects. The water extract of Nepeta before addition of silver nitrate solution, and color change dynamics caused by biosynthesis are shown in Figure N2.

Regarding the effect of temperature on biosynthesized silver nanoparticles, the results described above were obtained on a samples stored in refrigerator (+5° C). At room temperature (with constant temperature 23°C), after 24-hour observation strong, visible precipitation took place. From the

above we can conclude that the process is more intense at room temperature than it is in refrigerated conditions. However, nanoparticles had tendency to agglomerate, the system was less stable, and the resulted in much stronger precipitation than that of the sample stored under refrigeration conditions.

The study of pH influence on the biosynthesis process of silver nanoparticles showed that process is more intense in alkaline medium. The pH of Catnip water extract was 5.7 and after mixing with silver nitrate equaled 5.1. Addition of sodium alkali solution rose the pH of the mixture up to 10.0. The color of mixture changed from a light brown to a dark green, almost black in few minutes, which proves once again, as it was described in scientific works multiple times, that biosynthesis process in such conditions runs with higher rate.

With conducted TEM x120,000 magnification images were obtained. The size of formed silver nanoparticles was to determined, their morphology and distribution was investigated. Silver nanoparticles biosynthesized by Nepeta Cataria L. water extract are represented as agglomerates. On image several such groups are spread and they are very similar to one another. In all of them many individual small particles are defined, however, many of them are united. It should be noted that visually no precipitation was observed in the solution at this time. As for the shape, it varies and particles are capped as transparent membrane is observed which surrounds dark content. Particle diameters range from 4 to 80 nm.

In the case of silver nanoparticles prepared by *Salvia sclarea L*. extract, the extremely strong aggregation is observed. In the image it appears in the form of large spots, few small particles are also presented though with an obvious tendency to coalesce. Unlike the first sample, a membrane-like formation can't be found and it indicates that AgNPs weren't capped which eventually could cause agglomeration. Size distribution is between 4-175 nm. Images are given on Figure N3.

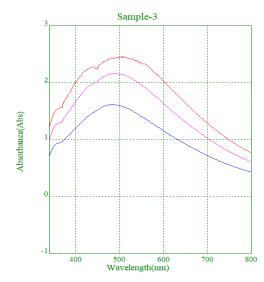
Antibacterial activity

As it was already mentioned above, the study of antibacterial activity of biosynthesized silver nanoparticles was conducted using so-called Spot Test method. List of used bacterial strains and results are given in Table N1.

A sample containing silver nanoparticles (N1) biosynthesized by *Nepeta cataria L*. extract showed good antibacterial activity. Out of ten bacterial strains tested, it wasn't able to affect only Staphylococcus aureus, while test blank extract (N3) affected only Enterococcus spp. Similar effect was not shown by silver nanoparticles prepared from *Salvia sclarea L*. extract (N2). Only three strains were sensitive to it, moreover, blank extract showed the same effect on two of them (N4).

Conclusion

Based on conducted experimental research we are able to conclude that Silver nanoparticles of optimal characteristics can be biosynthesized using water extract of *Nepeta Cataria L*. Appropriate conditions of biosynthesis were determined and as it was expected, process proved to be easy and has low costs. Obtained AgNPs have potential to be used as antibacterial agent.



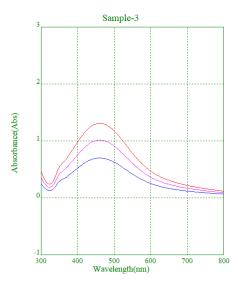


Figure N1. UV-Vis absorption spectra of silver nanoparticles biosynthesized with N.cataria (left) and S.sclarea (right) extracts

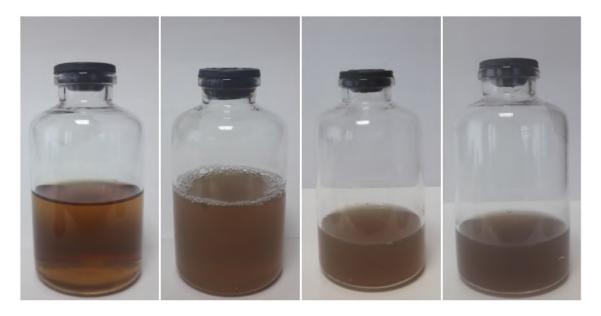


Figure N2. Water extract of Nepeta cataria before adding AgNO3 solution and mixed solutions after launching the biosynthesis in 1, 24, 48 hours (from left to right)





Figure N 3. a-silver nanoparticles biosynthesized with Nepeta cataria extract; b-silver nanoparticles biosynthesized with Salvia sclarea extract;

Table N1. Results of antibacterial activity of biosynthesized silver nanoparticles

Bacteria	Sample №1	Sample №2	Sample №3	Sample №4
Klebsiella spp	4+	-	-	-
E-coli	1+	-	-	-
Pseudomonas aeruginosa	4+	-	-	-
Streptococcus spp	4+	2+	-	-

Enterococcus spp	2+	2+	2+	2+
Shigella spp	2+	-	-	-
Salmonella spp	4+	-	-	-
Enterobacter spp	3+	2+	-	2+
Proteus spp	2+	-	-	-
Staphylococcus aureus	-	-	-	-

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Sustainability Performance Assessment of the Participatory Guarantee Systems: A case study in Beijing Farmers Market

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ABSTRACT

Among the range of incentives that might motivate farmers to adopt more sustainable practices, focus is given on the role that institutional innovations such as Participatory Guarantee Systems (PGS) could play in the transition to sustainable agriculture. PGS are established by producers, consumers, local authorities and other interested stakeholders, and ensure that agreed sustainable agricultural practices are adopted. Despite the growing popularity, there is no an experimental assessment of sustainability performance of PGS in order to better understand the role of PGS in sustainable agriculture. The objective of this study is to (a) assess the sustainability performance of PGS comprehensively, (b) to perform a systematic assessment of synergies and trade-offs between sustainability dimensions and themes and (c) to quantify the real influence of the selected sustainability themes on the least evolved theme. The Sustainability Assessments of Food and Agriculture Systems (SAFA) Guidelines published by the Food and Agriculture Organization (FAO) provide a transparent and aggregated framework to encompass all aspects of sustainability, as well as to understand how strength, weakness and progress could be tackled in the farming systems. This study used the indicator-based SAFA consistent SAFA Tool to assess sustainability performance of Beijing Farmers Market (BFM) PGS in China. Based on the respective sustainability scores, the synergies and trade-offs between sustainability dimensions and themes were analyzed using the non-parametric Spearman correlation test, and a linear regression analysis was applied to identify the influence that selected sustainability themes have on a poorly rated theme. The results displayed trade-offs between "Economic Resilience" dimension and other three sustainability dimensions, due to "Vulnerability" theme which was a most challenging and poorlyrated theme. At the same time, the "Holistic Management", "Biodiversity" and "Water" themes had a significant effect (P<0.05) with the capacity to decrease vulnerability level by 43.4%, 41.4% and 37.3%, respectively. Through its positive influence, "Social Well-Being" dimension enhanced the achievement of sustainability goals on other dimensions. The study further argues that with a committed and supportive consumer base PGS could become a reservoir of social capital to build a fair and sustainable community. This study presents a new perspective leading to a guideline for other PGS initiatives those early in the sustainability journey.

Key words: PGS, SAFA, sustainability performance assessment, synergies, trade-offs

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Introduction

Institutional innovations are considered as new regulations and ways of re-organizing the relationships between producers and organizations (actors) in the food system [1] by pushing the boundaries of the traditional roles of market and institutional intermediaries [2]. One of the examples

of the institutional innovations is the PGS, which are defined as locally focused quality assurance systems. They certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange [3].

PGS offer producers a wide range of benefits

such as market access, farmer empowerment, improved social bonds, regular sales, cost-saving practices, a better management of natural resources and enhanced food security. Hence, PGS play a vital in to reduce food insecurity and poverty problems among rural farmers, thereby fostering more sustainable livelihood [4]. Moreover, PGS can be used as a tool to improve organic agriculture and alternative certification system [5]; intensify knowledge sharing and disseminate good agricultural practices among farmers [6]; facilitate peer-to-peer process, enhance food sovereignty for local markets [7]. PGS have the potential to enable transformation towards sustainability [8], but convincing evidence is needed on how PGS promote the transition to more sustainable food system [9]. Although previous studies scientifically covered individual components of PGS [10-12], a deep analysis that covers key aspects of sustainability and quantitative analysis of interactions between sustainability objectives is still absent.

different frameworks have Many been developed [13-15], but most of them are unclear in agreeing on how to asses sustainability [16,17]. This, perhaps, is partly due to lack of an agreed-upon definition of sustainability [18] and incompatible approaches to performance analysis in the field of sustainable development [19]. For instance, Life Cycle Assessment (LCA) tools quantitatively evaluate environmental impact of a product considering the use of resources and emission of pollutants [20], but ignore the economic and social dimensions [21]. Furthermore, the Framework for Assessing the Sustainability of Natural Resource Management Systems (MESMIS, for its acronym in Spanish) has been applied to more than 20 case studies across Europe and Latin America in order to evaluate agricultural sustainability [22-24]. The operative structure of MESMIS framework is based on a six-step evaluation. The first three steps are related to a system characterization, the identification of key aspects and the selection of indicators with respect to the three sustainability dimensions (environmental, economic and social). The last three steps are assessed through mixed (qualitative and quantitative) techniques and multi-criteria analysis based on the information obtained from the indicators [25]. However, MESMIS framework excludes key indicators (e.g., stakeholder participation) from being included in the assessment [26]. The system-oriented

sustainability assessment approaches such as Response-Inducing Sustainability Evaluation (RISE) [27,28] evaluate sustainability of farm management with respect to the three sustainability dimensions like MESMIS, but with limited number of indicators. The precision and scope of more than 30 different approaches identified in literature were comprehensively compared, and it was concluded that none of them captures all aspects of sustainability assessment [29]. The divergence between the proposed sustainability assessment tools and their components to measure "what matters to whom and how" reinforces the point that assessment frameworks remain fragmented. This means that they need to be holistically approached and harmonized, and all essential components of sustainability should be integrated, establishing a "common language" for sustainability assessment that is relevant to governments, policy-makers and agricultural holdings whether they are big companies or small-scale producers. To close this gap, Food and Agriculture Organization of the United Nations (FAO) developed the Sustainability Assessments of Food and Agriculture Systems (SAFA) Guidelines, providing a globally applicable aggregated framework for sustainability assessment [30]. SAFA Guidelines are comprised of 4 dimensions, 21 themes and 58 sub-themes with specific sustainability objectives (Table S1). Based on SAFA Guidelines, FAO created SAFA Tool, which is an indicator-based tool used to conduct sustainability assessment by supporting trade-off and synergy analysis.

The aim of this study is to apply SAFA-consistent SAFA Tool to assess sustainability performance of BFM PGS to address the question of whether and to what extent PGS are able to provide a transition towards sustainable agriculture which has governance, environmental integrity, economic and social dimensions. Specifically, sustainability performance scores will be used to analyze the synergies and trade-offs between sustainability dimensions and themes, as well as to quantify the real influence of the selected themes on the least evolved theme.

The sustainability performance assessment of BFM PGS and identifying interactions between sustainability goals provide a roadmap, leading to an evidence-based and action-oriented cyclic process conducive to the sustainable development of other PGS initiatives worldwide.

2. Materials and Methods

2.1 SAFA Tool Approach

SAFA Tool approach is engaged with the provision of a standardized metrics to guide assessments, which is detailed in terms of what

"sustainability" means in a practical context [31]. SAFA Tool assesses the sustainability performance of the agricultural holdings with respect to 21 themes and 58 sub-themes identified in SAFA Guidelines (Figure 1).

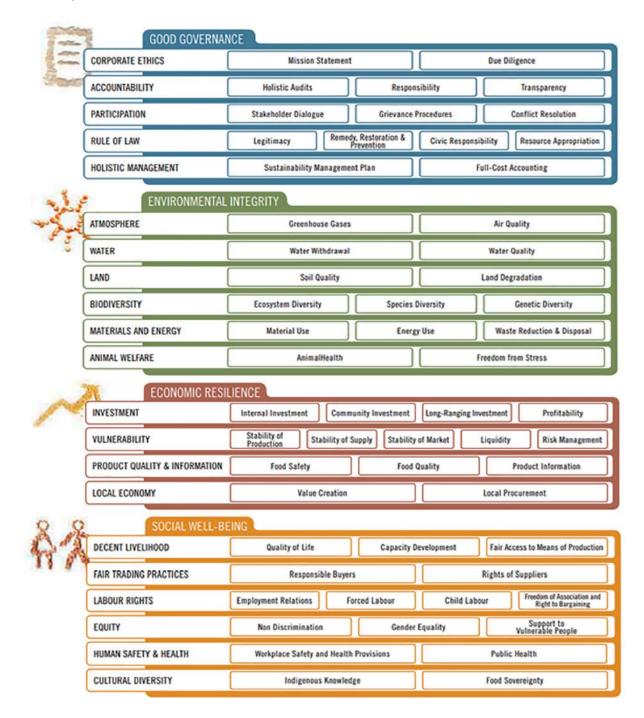


Figure 1. Overview of SAFA dimensions and constituent components (themes and sub-themes) *Source:* Food and Agriculture Organization of the United Nations (FAO, 2014a).

For each theme and sub-theme, SAFA Guidelines outline goals and objectives that are globally comparable at all contexts. For instance, for the theme "Land" the goal is "No land is lost

due to surface sealing or mismanagement of arable lands and pastures, and soil fertility is preserved and enhanced". Whereas for the sub-theme "Generic Diversity" the objective is "The diversity of populations of wild species, as well as the diversity of varieties, cultivars and breeds of domesticated species, is conserved and improved". Each subtheme contains a number of indicators that express sustainability performance on a scale from 0 to 100%. 0% represents an unacceptable state that does not meet the sustainability objectives, whereas 100% represents a situation where all implemented farming activities are related to the "best" achievable objective.

SAFA tool can also be used to cover the farming activities for one year, which provides a benchmark, pointing out critical areas for further improvement. This is especially important for establishing threshold values for the future sustainability assessment. Science-based in nature, SAFA Tool can also be applied to case studies. However, it is not a tool of rating, which is appropriate for a product-specific sustainability, such as LCS approach, and is focused on farms rather than the lifecycle of a product.

2.1.1 Determining the Sustainability Performance

SAFA Tool approach starts with the mapping of the assessed entity and review of relevant sub-themes and indicators based on sustainability objectives and context, followed by the determination of a performance score for each indicator and finally, the visual representation of the sustainability report based on the performance scores.

SAFA Tool (Version 2.2.40) contains a total of 116 performance indicators that facilitate measuring progress towards sustainability across the 21 themes and 58 sub-themes (Appendix 1, Table A1). In this study, indicators used for the sustainability performance assessment have been selected according to the following criteria [32,33]:

Parsimony: selection of minimal but manageable set of indicators,

Consistency: the indicators are complementarity for an appropriate interpretation,

Sufficiency: the indicators are comprehensive to integrate all sustainability goals.

For each sub-theme, all indicators in the governance, economic and social dimensions are integrated into the calculation with the weight 1, and the weight is distributed evenly among indicators within each sub-theme (Table 1, A side). No need for weighting if there is only one indicator in the sub-theme (e.g., Community Investment), and if the sub-theme (e.g., Quality of Life, Stakeholder Dialogue) contains more than one indicator, the mean is taken out of the respective number of scores. If the mean is not possible, the lower score is given to the respective sub-theme.

Table 1. Overview of the different weights for the indicators in the governance, economic, social and environmental dimensions Source: (FAO, 2014a).

The number of indicators per subtheme is:	Indicator weight in the governance, economic and social dimension			
1	100 percent			
2	50 percent			
3	33 percent			
4	25 percent			
Combination of indicator types in the environmental dimension	Maximum potential indicator points in the environmental dimension			
T - R - P	1+2+3= 6 points			
T- R - P - P	1+2+3+3=9 points			
R - P - P - P	2+3+3+3 = 11 points			
R - P - P - P - P	2+3+3+3+3=14 points			
T - R - P - P - P	1+2+3+3+3 = 12 points			

On the other hand, three types of indicators are differentiated in the environmental dimension, and the following weighting applies to the indicators in the environmental dimension:

Target (T) indicators = 1 point Practice (P) indicators = 2 points Performance (P) indicators = 3 points

The combination of indicators in the environmental sub-themes is presented in Table 1 (B side). Performance indicators (e.g., "Soil Quality") or those that are considered to be direct measurement

from an operation itself receive the most weight. Practice indicators (e.g., "Soil-Improvement Practices") or those that are measured by reference to a certain level of good performance are given the second most weight. Target indicators (e.g., "Water Conservation Target") are related to the existence of plan, monitoring, documentation and strategy with a particular sustainability target and are given the lowest amount of weight. Examples of these three types of indicators are given in the Table 2.

Table 2. Examples of different types of environmental indicators for assessing sustainability performance.

Indicator type	Indicator example	Potential responses
Performance indicator	Does the enterprise's operation save seeds, or engage with breeding work to	Yes/no/partial
i ciroimanee indicator	conserve traditional and/or rare breeds on farm?	Percentage
Practice indicator	What activities and practices have been implemented that have effectively increased	Yes/no/partial
	the quality and fertility of soils?	List of practices
Target indicator	Has the enterprise set a target for reducing water consumption or water withdrawals?	Yes/no/partial

All indicators in SAFA Tool have a 5-scale rating (Table 3), and the rating increases gradually as the performance score goes up from unacceptable to best (Table 4).

Table 3. Rating scales for the SAFA indicators Source: (FAO, 2014a).

Rating scale	Description: The indicator is rated
Best / 80 – 100%	at the top level of sustainability performance
Good / 60 – 80 %	at the good level of sustainability performance
Moderate / 40 – 60 %	at the moderate level of sustainability performance
Limited / 20 – 40 %	at the limited level of sustainability performance
Unacceptable / 0 – 20 %	at the unacceptable level of sustainability performance

Indicators which are considered irrelevant during the contextualization process can be omitted. For instance, indicator with the same name in the sub-theme "Employment Relations" may be irrelevant for small-scale organic producers since they mostly rely on the family work. But the omission of this indicator does not receive "unacceptable" score

or 0 percent, rather a potential maximum score of this indicator is subtracted from the total maximum potential score of the sub-theme to determine the overall rating for that sub-theme.

On the other hand, if the indicator is deemed irrelevant without a justification, the final rating for the omitted indicator is 0 percent or "unacceptable".

This score then is averaged with other indicator scores to calculate the sub-theme rating. Thus, if a sub-theme (e.g., "Internal Investment") contains only one indicator, and it is omitted without justification, the sub-theme rating is 0 percent, or "unacceptable". If a sub-theme (e.g., "Product Information") contains more than one indicator, and one of

them is omitted without justification, 0 percent or "unacceptable" score is averaged with the other indicator ratings to determine the overall sub-theme rating. To obtain a performance score at the theme level, an arithmetic mean of the sub-theme scores is calculated, if not available, the lowest score is given to the respective theme.

Table 4. Different rating scales for the indicators in the governance, economic, social dimensions (A), and environmental dimension (B, by type) Source: (FAO, 2014a).

	Ratings (A)	Ratings (B)		
Rating scale	Indicator points	Target indicator points	Practice indicator points	Performance indicator points
Best / 80 – 100%	5	1	2	3
Good / 60 – 80 percent	4	0.75	1.5	2.25
Moderate / 40 – 60 percent	3	0.5	1	1.5
Limited / 20 – 40 percent	2	0.25	0.5	0.75
Unacceptable / 0 – 20 percent	1	0	0	0

Finally, all data set are integrated into a sustainability performance report, and this process is called data visualization. Data Visualization is a way of depicting the information in a polygonal form allowing to see the concepts and relationships.

2.2 Description of Beijing Farmers Market (BFM) PGS

This study was carried out in BFM PGS that is established in 2010. BFM PGS was chosen using the following criteria:

It is operational at local context for at least five years;

BFM PGS initiative is achieved local recognition thanks to its four founding principles – health, ecology, fairness and care which is endorsed by IFOAM;

BFM PGS are self-financed and linked to markets;

BFM PGS consists of 66 small-scale organic farms, and its dedicated team of 25 employees (including volunteers) runs a weekly market and two community stores that offer their customers a wide

range of organic products throughout the year. Most of the farms are located around the city of Beijing, and a few of them are in Hebei Province. Only 46 out of 66 small-scale member farms were selected just because they were actively-involved in sales fairs which were regularly held at the center of Beijing and field visits to farms which continuously apply PGS standards. The rest 20 farms were not selected as a target group, since they had just started to apply PGS standards at the probation period. In addition to 46 member farms, interviews were also conducted with relevant 78 more stakeholders (management body of BFM, researchers, food bloggers, consumers and volunteers working at the community markets) who had a leading role in the decision-making process.

Interviewed farmers were from Shunyi, Changping, Haidian, Fangshan, Huairou, Daxing districts of Beijing and Tangshan and Zhangjiakou districts of Hebei province (Figure 2). Selected farmers were mainly organic vegetable and fruit growers. Interviews and field observations were the primary source of information, and data collection process was carried out using two farm questionnaires.

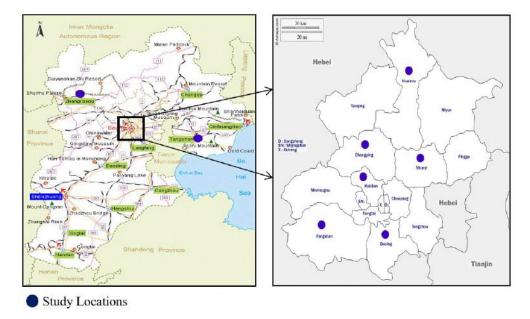


Figure 2. Map of the study locations

2.3 Data Collection and Analysis

Data collection was done between August 2020 and February 2021. Assessment process is illustrated in five steps (Figure 3). Step 1 started with literature and SAFA methodology reviews and preparation of the farm questionnaires. The preparation process was supplemented with the member farmers and key informants from the management body of BFM PGS in order to understand the operating context of BFM PGS. SAFA Tool indicator set was contextualized to find relevant indicators for the study

area. From a set of 116 indicators, 80 indicators (47 out of 58 sub-themes) were applied (Appendix 2) to assess sustainability performance of BFM PGS based on the "contextualization" described above.

Step 2 included an interview with the farmers and management body of BFM PGS at the market-place using farm questionnaires. Interview process started with a question-and-answer session on the target indicators, followed by a farm visit especially for collecting the farm specific information on the practice-based and performance indicators.

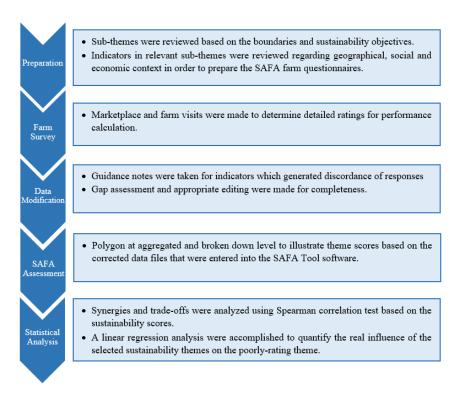


Figure 3. *Illustration of data collection and analysis process*

In order to ensure that all of the relevant indicators were answered correctly, each of the farm questionnaires was checked with the farmers and management body of BFM PGS for completeness in Step 3. Guidance notes were taken, and identified gaps were communicated back BFM PGS staff and the respective farm for appropriate editing. In the next step, the completed data sets were integrated into SAFA Tool software to compute the sustainability performance scores for each theme.

In the final step, based on the sustainability performance scores obtained in step 4, the synergies and trade-offs were analyzed using the non-parametric Spearman's rank-correlation test [34]. The coefficients ranged between $0 < rs \le +1$ represented synergies or positive correlations, while the coefficients ranged between $0 > rs \ge -1$ represented trade-offs or negative correlations. Additionally, a linear regression analysis was conducted to identify mathematical dependences between selected sustainability themes. All statistical analyses were made using IBM SPSS Statistics version 21 [35].

It must be noted that some performance indicators related to "Water Quality" and "Soil Quality" sub-themes in the environmental dimension were unavailable at the farm level since most of the small-scale farms were less able to test their soil and water quality due to high analysis costs. However, considering that these two themes were vital in terms of evaluating the environmental sustainability and

also in order for this study to provide high quality assessment, water and soil samples were taken from the fields and analyzed.

The soil fertility status of organic vegetable fields was surveyed after the harvest of cool-season vegetables in November. The soil samples were taken at a depth of 0-20 cm using soil sampling probe. Furthermore, in order to test concentrations of water pollutants tube wells were pumped to remove stagnant water before fresh water samples were collected. A total of 30 (15 water and 15 soil) samples were analyzed for the water pH, electrical conductivity (EC), ammonium-nitrogen (NH4+-N) and nitrate (NO₃-N) levels, soil pH, soil organic matter (SOM), nitrogen (N) phosphorus (P) and potassium (K) contents at the Chinese Academy of Agricultural Sciences (CAAS) laboratory in the city of Beijing. The threshold values [36-43], for the selected indicators were presented in Appendix 1, Table A2.

3. Results and Discussion

3.1 Sustainability Performance Assessment of BFM PGS

Using SAFA Tool, this study helped BFM PGS to benchmark their farming activities against the sustainability objectives defined in SAFA Guidelines.

The sustainability performance of BFM PGS regarding the respective dimensions are presented below (Figure 4):

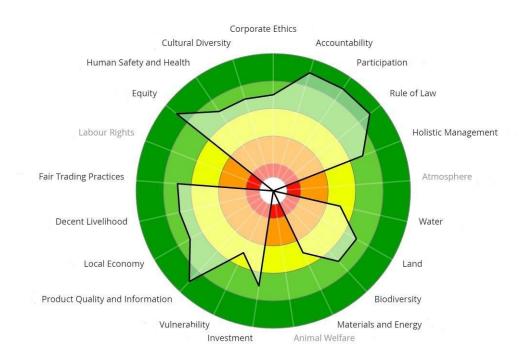


Figure 4. Sustainability Performance report of BFM with respect to SAFA themes.

"Good Governance" dimension: the result showed that all farms performed well with respect to "Corporate Ethics", "Accountability", "Participation", "Rule of Law" and "Holistic Management" themes. The main reason of this performance score was that BFM PGS particularly emphasized collective action, transparency, democratic structure and independent governance in order to embrace social justice and community welfare which in turn positively impacted its performance in the governance context.

"Environmental Integrity" dimension: Farms showed a good performance score with respect to the "Biodiversity" theme (72%), even though the overall performance score of the environmental dimension (60%) was lower than other dimensions. This low score was attributed to "Water" (52%) and "Material Use" (51%) themes as the majority of the farms found themselves in a region (Beijing Plain) with high groundwater withdrawals due to intensive agricultural irrigation [44]. Moreover, a rapid urbanization and migration to the cities from an area where the farmers live negatively affected their material consumption patterns.

At the same time, water and soil test results (see Appendix 1, Table A3-A4) showed that "Water Quality" was the sub-theme where the all farms managed to perform well. Whereas for "Soil Quality" sub-theme, the highest variability among farms in the performance scores was found as some farms have far exceeded the proposed threshold levels (e.g., soil pH, K and P content) (see Appendix 1, Table A4-A5).

"Economic Resilience" dimension: Farms performed well with respect to "Product Quality & Information", "Investment" and "Local Economy" themes - 85%, 80%, 80%, respectively. On the other hand, no single farm performed better than 58% for "Vulnerability" theme. This indicates that for "Vulnerability" theme sustainability objectives formulated in SAFA Guidelines were relatively difficult to achieve for farms.

"Social Well-Being" dimension: High perfor-

mance scores were achieved with respect to "Decent Livelihood", "Fair Trade Practices", "Human Safety" and "Health and Cultural Diversity" themes - 79%, 80%, 81%, 79%, respectively. At the same time, 100% of goal achievement was realized for "Equity" theme. Even though farmers had access to information and knowledge through regular farm visits, sharing meetings and discussions with the consumers, scientists and researchers, the level of contact between the agricultural extension services (AES) and the farmers was too weak (see Appendix 1, Table A6). Only 25% of the farmers were visited by the AESs during 2019. The number of farmers visiting the extension services was 33% during the same period. But, a mutual exchange of information with the extension agencies can help some farmers to gain a clearer insight into balanced fertilization to improve their management and production skills which in turn will positively affect their environmental sustainability performance. This is the synergetic effect of the social dimension on the governance and environmental dimension.

The key determinants that may affect sustainability performance of BFM PGS are summarized in Appendix 1, Table A7.

3.2 Analysis of Interactions within Sustainability Dimensions and Themes

In the previous sub-section, sustainability performance of BFM PGS in terms of the dimensions and themes was analyzed. While BMF PGS achieved high scores respect to a large number of themes, it did not perform well across all dimensions and themes. This justifies the importance of further assessment of synergies and trade-offs between dimensions and themes [45]. When analyzing the dimensions individually, high performance scores were identified in "Social Well-Being" (84%), "Good Governance" (83%) and "Economic Resilience" dimensions (75%), and low performance score in "Environmental Integrity" (60%) dimension.

Table 7. SAFA Tool sustainability assessment scores for the respective themes

Custoin chility thomas	BFM PGS			
Sustainability themes	(N = 46) Mean	Std. Deviation		
Corporate Ethics	81.553	1.267		
Accountability	92.395	2.881		

Participation	82.395	1.685
Rule of Law	84.526	2.826
Holistic Management	76.921	4.456
Water	52.763	2.454
Land	64.763	3.267
Biodiversity	72.027	3.192
Materials and Energy	51.579	4.221
Investment	80.842	1.853
Vulnerability	57.948	3.676
Product Quality & Information	85.421	3.301
Local Economy	80.711	2.205
Decent Livelihood	79.947	2.610
Fair Trading Practices	80.263	2.854
Equity	100.000	0.000
Human Safety & Health	81.421	2.201
Cultural Diversity	79.895	3.178

Based on the sustainability performance scores in Table 7, synergies and trade-offs were analyzed between dimensions and themes using Spearman correlation test. Synergies were found between governance and social dimensions (10%). To a lesser extent there were also synergies between environmental and social dimensions (1%) (Table 8).

Table 8. Overview of synergies and trade-offs between sustainability dimensions.

Dimensions Good Governance Good Governance 83%		Environmental Integrity	Economic Resilience	Social Wellbeing
Environmental Integrity	-13%	60%		
Economic Resilience	-24%	-14%	75%	
Social Wellbeing	10%	1%	-8%	84%

Note: Green color and yellow medium color indicate synergies whereas red color indicates trade-offs

In the theme level (Table 9), in "Good Governance" dimension, the highest degree of synergies was found between "Corporate Ethics" and "Rule of Law", and between "Holistic Management" and "Rule of Law" followed by "Corporate Ethics" and "Participation". While the synergies between "Rule of Law" and "Participation", and between "Holistic Management" and "Participation" were low. In "Environmental Integrity" dimension, synergies between "Biodiversity" and "Water" themes were high. At the same time "Materials Use" theme showed the lowest degree of synergies with the other environmental themes. In addition, environmen-

tal themes showed the significant synergies with economic and governance themes. In "Economic Resilience" dimension, synergies between "Investment" and "Local Economy" and between "Investment" and "Product Quality & Information" themes were higher than the synergies between "Local Economy" and "Product Quality & Information" themes, whereas "Vulnerability" showed the lowest degree of synergy with "Product Quality & Information" theme. In "Social Well-Being" dimension, "Fair Trading Practices" had the highest synergies with other social themes, except "Decent Livelihood" theme.

Dimensions Biodiv Material Corporate Ethics Trading Themes Managem Land Quality Econom Liveliho Diversit ability bility Inform Practi Corporate Ethics Accountability -0.004 -0.126 -0.237 +0.102Participation 0.224 -0.12 1 Rule of Law 0.32 -0.032 0.134 Holistic -0.053 -0.019 0.226 Water -0.118 0.296 -0.077 0.066 -0.066 -0.135+0.011Biodiversity -0.041 -0.129 -0.205 -0.12 0.159 -0.073 Material use 0.039 -0.191 0.163 -0.063 0.078 0.162 -0.069 -0.198 -0.046 -0.215 -0.012 -0.006 0.034 0.084 -0.098 0.127 Vulnerability 0.247 0.057 0.049 -0.129 -0.029 Product Quality & 0.257 0.281 -0.095 -0.014 -0.272 0.217 -0.31 0.176 0.123 0.03 -0.075 0.274 0.253 -0.119 -0.206 1 0.29 0.106 -0.074 0.022 0.193 0.079 Local Economy -0.21 0.096 0.072 -0.305 -0.147 0.165 0.192 0.013 0.068 0.136 -0.016 -0.156 0.22 Livelihood Fair Trading -0.169 -0.231 -0.04 -0.015 0.12 -0.001 0.14 0.203 -0.036 -0.005 0.154 0.075 Human Safety & -0.218 0.274 0.224 0.114 -0.139 -0.07 0.241 Cultural Diversity -0.202

Table 9. Spearman correlation values between sustainability themes

Note:*- Correlation is significant at the 0.05 level (2-tailed); **- Correlation is significant at the 0.01 level (2-tailed)

It was also found that "Economic Resilience" dimension had the trade-offs with all sustainability dimensions (Table 9) due to "Vulnerability" theme. There were also trade-offs between "Environmental Integrity" and "Good Governance" dimensions. Furthermore, between theme levels (Table 9), "Vulnerability" theme showed the significant trade-offs (P<0.05) with "Accountability" and "Holistic Management" themes in "Good Governance" dimension on the one hand, and with "Water" and "Biodiversity" themes in "Environmental Integrity" dimension on the other hand. In addition, "Vulnerability" theme also had the trade-offs with social themes such as "Local Economy" and "Decent Livelihood". Tradeoffs between the theme levels in all dimensions were even higher than the synergies. Whereas the

trade-offs within the theme levels in all dimensions were lesser than the synergies.

3.3 Regression Analysis

A regression analysis was performed to generate a mathematical equation in order to demonstrate the statistical dependency between selected sustainability themes. The Sustainability Performance Report (Figure 4) provided information regarding each theme individually, and the dependent variable was assigned to "Vulnerability" theme which was a challenging and less evolved theme from BFM PGS point of view. Furthermore, this theme seemed to be poorly correlated with other themes (Table 9).

The equation (1) captures the true relationship with the predictors, where subscript X represents the associated themes.

$$Y_{vulnerability} = 160.737 - 0.434X_1 - 0.373X_2 - 0.414X_3 - 0.255X_4$$
(1)

 $X_1 =$ "Holistic Management" theme,

 $X_2 =$ "Water" theme,

 $X_3 =$ "Biodiversity" theme,

 X_{A} = "Material Use" theme,

From Table 10, it can be seen that the predictor variables of "Holistic Management", "Water" and "Biodiversity" are significant. Whereas p-value for

"Material Use" theme (0.059) shows that the relationship is not statistically significant. The coefficients indicate that for every additional increase in "Holistic Management", "Water" and "Biodiversity" theme, it can be expected the negative tendency of the "Vulnerability" theme to decrease 43.4%, 37.3% and 41.4% respectively.

Coefficients ^a Variables Std. Error p-values 160.737*** Constant 18.634 .000 -0.434*** Holistic Management -3.361 .002 -0.373*** Water -2.924 .006 -0.414*** .004 Biodiversity -3.068 Material Use & Energy -0.255 .059 -1.956

Table 10. *Interactions between the sustainability themes*

Note: ***- Significant at the 1 percent level; a - Dependent Variable: "Vulnerability"

4. Discussion

BFM PGS has high scores in "Good Governance", "Social Well-Being" and "Economic Resilience" dimensions, and low score in "Environmental Integrity" dimension. This is the characteristic of PGS where the effectiveness of the market regulation comes from the mutual supervision between market organizers and participants, and economic gains of the small-scale farmers are high because of getting direct access to consumers. This finding is consistent with other studies, which reported positive impacts of PGS as a mean for empowering small-scale farmers and local communities [46-47], as well as facilitating access to markets and strengthening domestic food systems [48]. This is also true for most PGS in the world - within the community stakeholders, especially producers and consumers act according to their common values and behavioral norms and also have a strong identity and even emotional belonging to each other [4]. These PGS have determined their own principles and ways of running the community in the original way in order to improve livelihoods of rural farmers.

Comparing inter-linkages between sustainability dimensions and themes, more trade-offs were found than synergies. Major trade-offs were seen between "Economic Resilience" dimension and other three dimensions. In addition, significant trade-offs were also observed between economic themes and other themes (especially governance and environmental themes) due to "Vulnerability" theme, emphasizing that specific focus is needed to improve "Vulnerability" theme. It is further clear that the vulnerability level might disrupt the volume of a production, stability of supply, as well as quality standards in the near future. In addition, there could be records of input supply shortages that revel that at least some farmers have unfavorable level of vulnerability to

certain inputs which in turn could affect economic sustainability as a whole.

On the contrary, synergies were found between "Social Well-Being" dimension and other sustainability dimensions (except "Economic Resilience" dimension). In addition to the synergies between "Social Well-Being" dimension and the other dimensions, there were also significant synergies founded between social theme "Fair Trading Practices" and governance theme "Holistic Management", which emphasizes the importance of "Social Well-Being" dimension through its positive influence in the other dimensions of sustainability.

After contrasting with a sustainability performance report (Figure 4) and Spearman's correlation coefficients (Table 9), "Vulnerability" theme was counted as the most challenging indicators, so a mathematical dependency equation was obtained. From the Table 10, it is obvious that "Holistic Management" theme was the most effective theme, with the capacity to decrease vulnerability level by 43.4%. The next effective themes in order of importance were "Biodiversity" and "Water" themes. Each of these explained vulnerability level decrease by 41.4% and 37.3% respectively following a doubling of applied units. The results also showed that "Material Use" theme affects vulnerability but not significantly. Possible explanation could be that a decreasing number of local input suppliers, gradual loss of traditional farming varieties and knowledge, popularization of hybrid seed and manure from industrial farms negatively affect farms' material consumption patterns, and further improvement in the material consumption patterns could decrease vulnerability level.

The significant effect of "Biodiversity" and "Water" theme can be explained by the fact that the protection of biodiversity and water resources are necessary to sustain the functioning of ecosys-

tems and human communities [30]. Therefore, the efficient water management practices and the availability of buffers in a form of species and generic diversity can help decrease a tendency of the vulnerability level.

4.1 Limitations of this study

Since interviewed farmers were mainly smallscale organic vegetable growers, "Animal Welfare" (including "Animal Health" and "Freedom from Stress" sub-themes) theme were omitted because of out of scope. In the study area, farming activities did not produce potentially polluting gaseous emissions, and operations did not depend on external energy inputs of any kind. In addition, sub-themes such as "Greenhouse Gases" and "Energy Use" can be examined more quantitatively using the life cycle assessment method in order to obtain reasonable and credible results. Therefore, "Atmosphere" theme (including "Greenhouse Gases" and "Air Quality" themes) and "Energy Use" sub-themes were omitted. Besides, "Full-Cost Accounting" sub-theme was also omitted since this is an emerging field, as well as a complex and difficult subject without an international consensus on its standards.

In "Social Well-Being" dimension many subthemes refer to the handling of employees, and therefore have less relevance for farms in the study area. Member farms of BFM PGS generally rely on family work in order to cope with the varying availability of labor, and participatory approach on a voluntary basis is encouraged as a labor-saving strategy among farmers living in the same area. That's why "Labor Rights" theme (including "Employment Relations", "Forced Labor", "Child Labor" and "Freedom of Association" and "Right to Bargaining" sub-themes) and "Rights of Suppliers" sub-theme were also omitted.

5. Conclusions

It is important to look at the factors that positively affect sustainability performance of BFM PGS and the future behavior of inputs and control mechanisms that are conceptually external to the farming system, when setting the right priorities and suggesting changes on farms or for policy implications. This highlights the importance of understanding a set of strategies to construct sustainability pathway.

Looking at the interactions between sustain-

ability themes (Table 9), "Vulnerability" theme was the most challenging to optimize as major trade-offs exist with other themes, and "Holistic Management", "Biodiversity" and "Water" themes exhibited a strong influence on "Vulnerability" theme (Table 10). Therefore, it can be concluded that a holistic view of sustainability with the longterm goal of improving resilience and adaptive capacity to potential shocks positively affects the negative tendency of "Vulnerability" theme since they proved to be interlinked. In addition, given the synergetic effect of "Social Well-Being" dimension, it can also be concluded that a specific attention on "Social Well-Being" dimension will shed light on the performance of the other sustainability dimensions.

This study has some policy implications. BFM PGS has a committed and supportive consumer base which in turn consumers become increasingly receptive to the farmers' products. Consumers who have a deep understanding and recognition of community-supported agriculture constantly appear in the market. They do not often satisfy with the support through purchase and are willing to provide support in the form of voluntary services. This means that with PGS a community could have a dedicated function to make this responsive consumer base become the labor, intelligence and communication medium of this quality assurance system. Without PGS, this format cannot go further, as it advocates the idea of achieving quality assurance through communication and collaboration between producers and consumers. This is an important strength of PGS as a socio-institutional function on building a truly sustainable community.

Consequently, this study encourages the policy-makers, non-government organizations, investors and people to be more receptive and responsible towards PGS and create positive conditions for sustaining PGS.

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Synthesis of Molybdenum Acid-containing Chelates and Their Usage in Broiler Feeding

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ABSTRACT

Synthesis conditions are established and molybdenum chelate compounds are synthesized with general formulas $[(H_2MoO_4)x \cdot gl] \cdot nH_2O$, (where x=1-3; gl-glutamine acid, n=2; 3) (I) and $[(H_2MoO_4)x \cdot Mt] \cdot nH_2O$ (where x=1;2; n=1; 2 Mt-methionine). The composition, individuality, and qualitative solubility in different solvents of the synthesized compounds are determined. Thermal analysis determines the nature of the thermal decomposition of the compounds. The degree of dissociation of chelates and the dissociation constants are determined based on the conductometric study. An experiment was conducted on a broiler to study biological activity. Dynamics of broiler live mass, absolute live weight gain, daily weight gain, fowl keeping, feeding expenditure for 1 kg. weight gain, broiler growth efficiency. It has been established that the use of chelate molybdenum in broiler feeding had a positive effect on all the above parameters and the optimal dose of chelate is 100-150 mcg. on one wing.

Key words: molybdenum, chelate, premix, broiler, glutamine acid, methionine.

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The actuality of the Issue

The role and importance of micronutrients as well as organic substances (amino acids, oxyacids, vitamins, etc.) in the normal growth and development of agricultural poultry and animals are now widely recognized. Micronutrients in bird premixes can be incorporated into two forms: both inorganic and chelate. In the inorganic form, salts are characterized by high toxicity, low degree of absorption, and efficiency, which is due to the formation of compounds that are difficult to dissolve and difficult to assimilate in the gastrointestinal tract of animals and birds. In the chelate form, micronutrients have low toxicity, high absorption capacity, and consequently, an increased degree

of efficiency when used in small doses, which in turn contributes to the ecological safety of the use of micronutrients in this form. It should be noted that in 2003, European countries passed a law on the maximum allowable doses of trace elements in the manure of agricultural poultry and animals: manganese, zinc, iron, cobalt, and copper. The solution to this problem, as already mentioned, is possible only by using the chelate form of these micronutrients. This fact is confirmed by the results of research conducted by foreign scientists [1-6] and results of research conducted by us over the years [17-23]. These advantages explain the increase in the production scale of premixes containing micronutrients in the form of chelates compared to non-chelated ones, which is increasing. Nowadays,

micronutrients Mn, Zn, Fe, Co, Cu, and I are included in the premixes according to the detailed norms of nutrition. However, the number of vital (essential) micronutrients that can not be replaced by other micronutrients and in the absence or deficit of which the likelihood is much higher, that the body can not grow normally and end the life cycle normally. Among these trace elements, our focus has been on molybdenum.

Molybdenum is characterized by low toxicity compared to other trace elements and is included in the enzymes xanthine oxidase, sulfite oxidase, and aldehyde oxidase. Has pronounced antioxidant properties, provides the breakdown and expulsion of toxic substances in the body, has a positive effect on the intestinal microflora, and actively participates in the synthesis of amino acids and vitamins (especially vitamin C). Has the ability to capture fluoride in the body, which ensures the maintenance of tooth tissue and gums in normal conditions and prevents caries. Molybdenum facilitates the absorption of iron by the body, which helps prevent anemia. Molybdenum deficiency contributes to the development of anabolic processes, weakening the immune system.

Georgia is an endemic center of molybdenum deficiency, however, as we have already mentioned, it is not included in the premixes, and in the composition of fertilizers it is used in the form of inorganic salts; This circumstance is explained by the fact that as a trace element in the composition of anions, it is characterized by a lower tendency to form compounds of the chelate form. According to the modern view of the ability to form complex microelements, which implies the use of a base nature chelate agent [27, 28], it is possible to synthesize molybdenum-containing chelates. Taking into account these factors, our work aimed to synthesize molybdenum-containing chelate compounds, physical-chemical research, and determine its impact on fowl growth and development, productivity, and physiological condition.

Aim and Objectives of the Research

The study aimed to study and establish the role of molybdenum, a micronutrient necessary for life, in broiler productivity, its impact on growth intensity, food compensation, organism viability, meat quality, and taste, and some morphological and biochemical parameters of the blood.

The study aimed to determine the optimal dose

of molybdenum, a micronutrient necessary for life, in broiler nutrition.

Research Materials and Methods

Microelement analysis - to determine the composition of molybdenum chelate compounds

Determination of melting temperature and diffractogram study - To determine the individuality of the chelates

Determination of solubility - to study the qualitative solubility of chelate compounds in different solvents

Conductometric research - determination of dissociation constant and dissociation quality of solutions containing solutions of chelate compounds

Thermographic analysis - to study the thermal stability of chelate compounds and the study the sequence of the thermolysis process

Weighing method - to determine the weight gain of the broiler

Accounting method of food consumption - to determine the conversion of food and consumed nutrients (protein, energy).

Research Results under Production Conditions

To obtain molybdenum chelate compounds with general formulas [(H2MoO4)x·gl]·nH2O, (where x = 1-3; gl-glutamine acid, n = 2; 3) (I) and $[(H_2MoO_4)x\cdot Mt]\cdot nH_2O$ (Where x = 1; 2; n =1;2 Mt-methionine). In the case of (I) molybdenum and glutamine acid are taken separately with 1:1; 1:2 and 1:3 molar ratios, and in the case of (II), also separate molybdenum acid and methionine are taken with 1:1 or 1:2 molar ratios. Each of them dissolves in a minimum volume of water under conditions of intense stirring and heating. To the chem solutions of glutamine acid and methionine is added ammonia up to a weak alkaline range (pH = 8). Chem solutions of molybdenum acid and glutamine acid and molybdenum acid and methionine are mixed in the above-mentioned sequence, filtered, and each of them is kept at room temperature. After a few days, the obtained compounds are filtered, washed with water, and ether, and dried at room temperature.

The composition and individuality of the obtained compounds are determined. Melting point is defined on the device melting point /SMP10 (Table 1), And it ranges from 190-240°C temperature range.

 Table 1.

 Some Physical Characteristics of the compounds containing Molybdenum Acid and Glutamine Acid

		Mol Mass	Melting t°c		Solul	oility		Conduc	tometric S Results	Survey
#	The formula of the Compound			Water	Alcohol	Acetone	Dmf	α Average	\mathbb{R}^2	Ж
1	[H₂M oO₄· gl]·2H₂O	345.10	190	+	+ t	+ t	+	0.8010	0.8615	0.0604
2	$[(\mathrm{H_2MoO_4)_2} \cdot \mathrm{gl}] \cdot 2\mathrm{H_2O}$	507.04	220	+	+ t	+	+	0.8012	0.9514	0.0342
3	$[(\mathrm{H_2MoO_4)_3} \cdot \mathrm{gl}] \cdot 3\mathrm{H_2O}$	686.96	240	+	+ t	+ t	+	0.7315	0.9118	0.0261
4	[H ₂ MoO ₄ Mt] ·2H ₂ O	347.19	210	+	+ t	+	+ t	0.7810	0.8820	0.0397
5	$[(\mathrm{H_2MoO_4})_2\mathrm{Mt}\!\cdot\!\mathrm{H_2O}$	491.12	230	+	+ t	+ t	+	0.8075	0.9078	0.0271

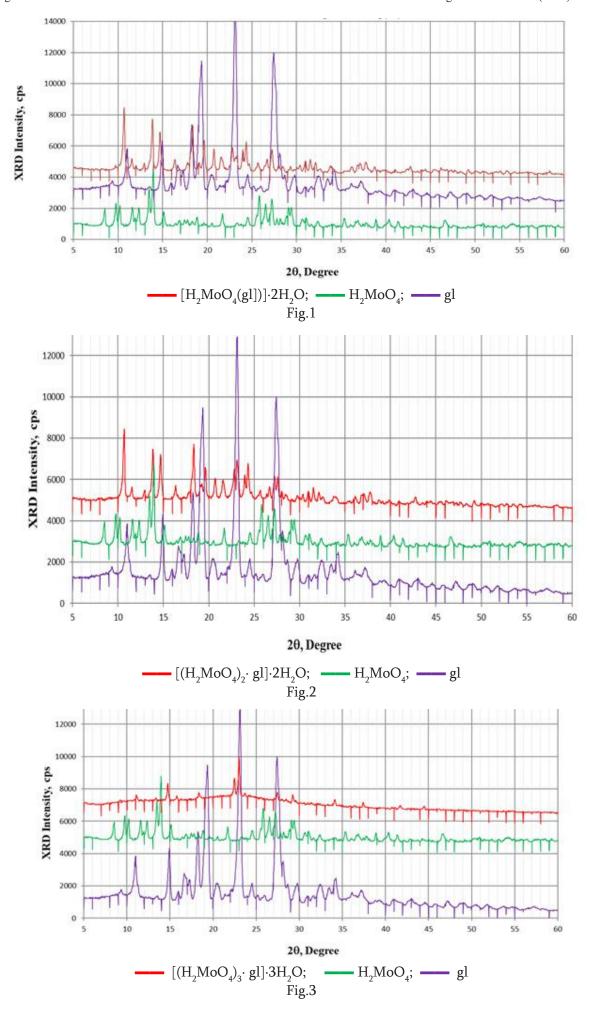
Dmf* - Dimethyl formamide;

The qualitative solubility of compounds in different solvents is determined, according to which they are characterized by good solubility in water and dimethylformamide, and relatively poor solubility in alcohol and acetone (Table 1).

To determine the degree of dissociation and dissociation constant of molybdenum chelate compounds, a conductometric study was performed on the device pH and Conductivity Sensor LE703. For compounds for this purpose: $[H_2MoO_4 \cdot gl] \cdot 2H_2O;$ $[(H_2MoO_4)_2 \cdot gl] \cdot 2H_2O;$ $[H_2MoO_4Mt]\cdot 2H_2O;$ $[(H_2MoO_4)_3 \cdot gl] \cdot 3H_2O;$ [(H₂MoO₄)₂ Mt·H₂O solutions were prepared in the concentration range from 0.025N to 0.00065N. The experiment was conducted on a thermostat at 25°C. The results of the experiment are presented in Table 1. R² - (Determination coefficient), is called the approximation reliability coefficient, which shows how close the experimental data is to the corresponding function of the graph. As can be seen from the table it is quite high and ranges from 0.8615-to 0.9514. The degree of dissociation, which is a variable, increases with

dilution. As for the values of the dissociation constant, it does not depend on the dilution of the solution, is the constant value, as shown in the table, is quite low and ranges from 0.0261-to 0.0604.

For $[H_2MoO_4 \cdot gl] \cdot 2H_2O$, compounds $[(H_2MoO_4), gl] \cdot 2H_2O$, and $[(H_2MoO_4), gl] \cdot 3H_2O$ X-ray diffractometric study was performed using ДРОН-4 $Cu_{k\alpha}(\lambda=0.154184nm)$ output. During the exposure, the samples were rotated on their plane by a special device - ΓΠ-13. Starting reactants Molybdenum acid and glutamine acid diffractograms were also taken for comparison. As can be seen from the analysis of diffractograms (Fig. 1-3), the location and intensities of the diffraction maximum characteristic of the obtained chelate compounds differ from the location and intensities of the diffraction maximum of the reactant compounds in other words do not contain characterizing diffraction maximums of the initial compounds (molybdenum acid and glutamine acid). This indicates that new individual compounds are being formed.



To study the thermal stability and sequence of the thermolysis process of the synthesized molybdenum chelate compounds $[H_2MoO_4 \cdot gl] \cdot 2H_2O;$ $[(H_2MoO_4)_2 \cdot gl] \cdot 2H_2O;$ $[H_2MoO_4Mt] \cdot 2H_2O;$ $[(H_2MoO_4)_2 \cdot Mt \cdot H_2O,$ a thermographic test was performed on the instrument: NETZSCH STA2500 the

heating rate of the sample is 10 degree/min (Table 2). As it became clear from the thermographic test, each thermogram is characterized by several exogenous and endogenous effects and with corresponding effects on the curve (Table 2).

Table 2. Results of a thermographic study of molybdenum acid and glutamine acid-containing compounds

	Formula	Melting	Mas	s loss,%	Broken-off	Solid Product of
#	Tormula	T ⁰ C	Practical	Theoretical	Molecule, Mol	Decomposition
		100	3.01	2.61	0.5H ₂ O	[H ₂ MoO ₄ · gl]·1.5H ₂ O
		130	7.87	8.04	1.5H ₂ O	[H ₂ MoO ₄ · gl]
1	$[H_2MoO_4 \cdot gl] \cdot 2H_2O$	240	23.71	23.80	0.5gl	$[H_2^2 MoO_4 \cdot g_{0.5}]$
		280	30.84	31.24	0.5gl	H_2MoO_4
		310	10.86	11,12	H ₂ O	MoO ₃
		100	4.0	3.55	H ₂ O	[(H _a MoO ₄) _a ·gl]·H _a O
		120	3.79	3.68	H,O	$ \begin{bmatrix} (H_2MoO_4)_2 \cdot gl] \cdot H_2O \\ [(H_2MoO_4)_2 \cdot gl] \end{bmatrix} $
2	$[(H_2MoO_4)_2 \cdot gl] \cdot 2H_2O$	230	15.93	15.62	0.5gl	$[(H_2MoO_4), g_{0.5}]$
	2 72 2	250	18.21	18.51	0.5gl	H ₂ MoO ₄
		300	11.51	11.12	$2H_2O$	2MoO ₃
		00	2.74	2.50	0.511.0	FT. 1. 6 1. 6 1. 6 1. 6 1. 6 1. 6 1. 6 1.
		90	2.74	2.59	0.5H ₂ O	$[H_2MoO_4Mt] \cdot .5H_2O$
	511.14 O.141 O.14 O.	110	8.21	7.99	1.5H ₂ O	[H ₂ MoO ₄ Mt]
3	$[H_2MoO_4Mt] \cdot 2H_2O$	240	24.23	23.98	0.5Mt	$[H_{2}MoO_{4}Mt_{0.5}]$
		270	30.87	31.54	0.5Mt	H ₂ MoO ₄
		320	10.99	11.12	H ₂ O	MoO ₃
		110	3.21	3.67	Н,О	$[(H_2MoO_4)_2 \cdot Mt]$
١.	[[[[]]]]]] [[]] [] [] []	260	15.23	15.77	0.5Mt	$[(H_2MoO_4)_2 \cdot Mt_{0.5}]$
4	$[(H_2MoO_4)_2 Mt \cdot H_2O$	280	18.14	18.72	0.5Mt	2H ₂ MoO ₄
		310	11.43	11.12	2H,O	2MoO ₃
1		I	I	1	2	5

Thermogravimetric analysis of the chelate compound [H,MoO4·gl]·2H,O shows that I endo effect (100°C) corresponds to a 0.5 mol H₂O breaking off (mass loss: practical 3.01%, theoretical 2.61%), at next endo effect (130°C) the remaining Mol H₂O is broken off (mass loss: practical 7.87%, theoretical 8.04%). As the analysis shows, at the next endo effect (240°C) there is an oxidation of 0.5 mol glutamine acid (mass loss: practical 23.71%, theoretical 23.80%) and it ends at 280°C (mass loss: practical 30.84%, theoretical 31.24%). The thermal decomposition of molybdenum acid corresponds to a strong exogenous effect at 310°C (mass loss: practical 10.86%, theoretical 11.12%) and the final product of thermolysis is molybdenum oxide MO₂, which was confirmed by qualitative and quantitative analysis of thermolysis residue.

The compound $[(H_2MoO_4)_2 \cdot gl] \cdot 2H_2O$ on the

thermogravimetric graph shows three endo and one strong exogenous effect. The first endo effect at 100°C corresponds to the break-off of 1 mol of water (mass loss: practical 4.00%, theoretical 3.55%), at the next endo effect (120°C) the second water molecule is broken-off (mass loss: practical 3.79%, theoretical 3.68%), at the third endo effect (230°C) oxidation of 0.5 mol glutamine acid takes place (mass loss: practical 15.93%, theoretical 15.62%). At the next endo effect (250°C) the oxidation of glutamine acid ends (mass loss: practical 18.21%, theoretical 18.51%). A strong exogenous effect (300°C) corresponds to the thermal decomposition of molybdenum acid (mass loss: practical 11.51%, theoretical 11.12%) and the formation of MO, molybdenum oxide. The obtained result was confirmed by qualitative and quantitative analysis of the residue.

The compound [H₂MoO₄Mt]·2H₂O thermogravimetric graph is characterized by several endos and one strong exogenous effect, indicating that it is decomposed in stages. In particular, the first endo effect at 90°C corresponds to the loss of 0.5 mol of water (mass loss: practical 2.74%, theoretical 2.59%). At the second endo effect at 110°C, there is a breakage of the remaining 1.5 mol water molecule (mass loss: practical 8.21%, theoretical 7.99%). The third endo effect at 240°C corresponds to oxidation of 0.5 mol Mt (mass loss: practical 24.23%, theoretical 23.98%). At the next endo effect at 270°C, methionine oxidation ends (mass loss: practical 30.87%, theoretical 31.54%). Thermal decomposition of molybdenum acid corresponds to a strong exogenous effect at 320°C (mass loss: practical 24.23%, theoretical 23.98%). The final product of thermolysis is molybdenum oxide MO₃. The obtained result was confirmed by qualitative and quantitative analysis of the thermal residue.

Thermal decomposition of the compound

[(H₂MoO₄)₂ Mt· H₂O begins at the end effect by breaking off 1 mol of water at 110°C (mass loss: practical 3.21%, theoretical 3.67%). At the next endo effect (260°C) the oxidation of the methionine molecule begins (mass loss: 15.23%, theoretical 15.77%). The endo effect at 280°C corresponds to the oxidation of the remaining 0.5 mol of methionine (mass loss: practical 18.14%, theoretical 18.72%). As in all other cases the thermal decomposition ends at a strong exogenous effect with the decomposition of molybdenum acid at 310°C and the formation of MO₃ molybdenum oxide (mass loss: practical 11.43%, theoretical 11.12%). The obtained result was confirmed by qualitative and quantitative analysis of the residue.

To determine the biological activity of the molybdenum chelate compound containing methionine acid, the effect of chelate on the broiler's productivity was studied. The experiment was conducted according to the following scheme:

Table 3.

Test scheme

#	Test Group	Number of Fowls	Rearing Period	Molybdenum Dose per 1 Wing (mcg)
1	Group 1	100	35	-
2	Group 2	100	35	50
3	Group 3	100	35	100
4	Group 4	100	35	150

We experimented on a meat cross "Ross 308" at "Roster" Ltd. located in the village of Teleti, Gardabani district, where we studied the effect of methionine-containing molybdenum chelate on the growth and development of broiler and meat quality. For the experiment, we took 400 wings of a 1-day-old chicken, which was divided into 4 groups (100-100 wings). One for control and three for trial.

During the experimental period, broiler rearing in all four groups was carried out with the same technological parameters, on deep bedding, and fully complied with the technological parameters set for broiler rearing.

During the experimental period, we studied the growth and development of a broiler with live mass dynamics. The broiler was weighed at 1,14,28 and 35 days of age, by individual weighing. We have

studied the absolute gain in different periods of weighing. We also studied maintenance and food consumption per 1 kg. weight gain. Feed coefficient as well as feed reimbursement, which means the ratio of spent feed to broiler weight gain.

The results of the experiment showed that the mass of one-day-old chicken was almost the same in all groups and ranged from 38.4 to 38.9 g. The relatively low live weight compared to the standard weight of one-day-old chickens (42g) is explained by the fact that they are obtained from the eggs of a relatively young mother hen's team (30 weeks) whose incubation egg weight is 52-54 g. The relatively low mass of a one-day-old broiler negatively affected its growth and development of the broiler. It has been scientifically established that the correlation between one-day-old chicken mass and final live weight is quite high at 0.7-0.75.

Table 4.

Broiler live weight dynamics

#	Test Group	Age, Day				
		1	14	28	35	
1	Group 1	38.5	457.9	1361.1	1793.0	
2	Group 2	38.4	464.2	1383.8	1829.5	
3	Group 3	38.9	473.8	1396.2	1866.8	
4	Group 4	38.9	487.8	1426.3	1880.3	

The highest live weight at 14 days of age was given to the fourth experimental group of broilers -487.8 in which the dose of the molybdenum added to feed was 150 mcg. This mass was 6.5% higher than the control group (P≥0.001). During this period, the broiler of the second and third experimental groups, where the dose of molybdenum was 50-100 mcg per wing, exceeded the control group by 1.4 and 3.3%, although the difference is uncertain.

At 28 days of age, the difference between the live weight of the fourth experimental group broiler and the same characteristic of the control group broiler was reduced to 4.8%, although even in this case the difference was uncertain ($P \ge 0.001$). And the

difference between the live weights of the second and third experimental groups and the broiler live weights of the control groups was also reduced to 1.7 / 2.6%. The difference is uncertain.

At 35 days, respectively at the age of slaughter, the highest live weight - 1880 kg was in the fourth experimental group and exceeded the control group by 4.9% (the difference is uncertain P≥0.001)

As can be seen from the live weight dynamics, the live weight in all groups in all age groups was almost 200-250 grams behind the Ross standards, the reason for which, as mentioned above, is the low initial live weight of one-day-old chickens.

Table 5.

Absolute weight dynamics

#	Test Group	Absolute Gain, g					
		0-14 days	14-28 days	28-35 days	0-35 days		
1	Group 1	419.35	903.2	431.9	1754.5		
2	Group 2	425.80	919.6	425.7	1791.1		
3	Group 3	434.9	922.4	450.6	1821.9		
4	Group 4	448.9	938.5	434.0	1841.4		

The calculation of the absolute gain showed that the absolute gain is different in different periods of growth. The maximum absolute gain was observed at the age of 14-28 days at 900-940 g. The highest absolute gain during this period was 938.5 in the

second experimental group and exceeded the control group by 3.9%. During the same period, absolute gain in the second and third experimental groups is 1.8-2.1% higher compared to the control group.

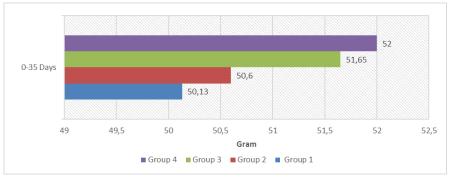


Fig.1. Changes in daily weight gain in all groups during the rearing period (0-35 days)

During the rearing period (0-35 days) in all groups, the daily gain varied between 50.3-52.0 g, and the highest was 52.0 grams in the fourth

experimental group and the lowest in the control group - 50.13 g.

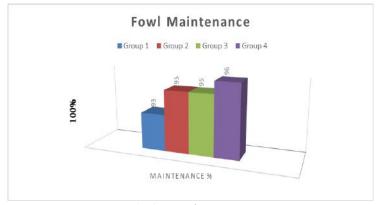


Fig.2. Fowl Maintenance

In the fourth test group, the maintenance is also the highest - 96%, which is 3% higher than the control group.

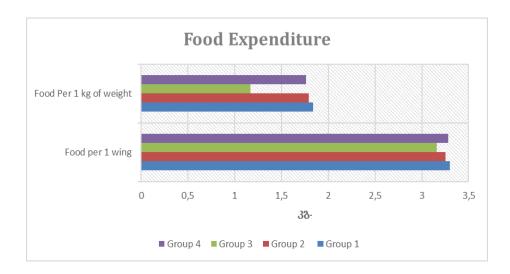


Fig.3. Food Expenditure

During the rearing period, the feed consumption was 3.16-3.3 kg per wing, and 1.71-1.84 kg per kilogram of weight gain. The lowest feed expenditure per 1 kg weight gain was 1.71 kg in the third experimental group. Which is 7.6% lower

than in the control group. Food consumption was lower by 2.8-4.5% compared to the control in the second and fourth experimental groups per 1 kg weight gain.

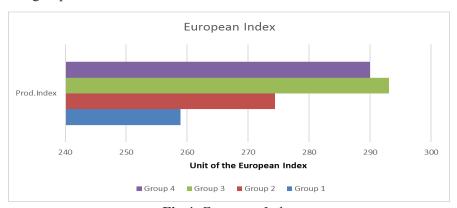


Fig.4. European Index

The productivity index was the highest in the third experimental group - 293.0 units, which is 34.2 units higher than the control group. The productivity index is 15-32 units higher in the second and fourth experimental groups.

At the end of the experiment, all four groups

Table 6. *Slaughter results*

of broilers were slaughtered at 35 days of age. The half-gutted slaughtered fowl's output was 80.1% in the control group, which was 2.0% lower than in the fourth group and 1% lower than in the second and third experimental groups.

Poultry Meat Output							
Test Group	Group 1	Group 2	Group 3	Group 4			
Number of slaughtered fowls	87	89	89	90			
Live weight of the slaughtered fowls, kg	156	161	165	168			
Live weight of 1 wing	1793	1809	1854	1866			
Half-gutted slaughtered fowl's weight	125	131	134	138			
Slaughter output %	80.1	81.4	81.2	82.1			
Weight of the half-gutted 1 wing	1440	1470	1500	1530			
Poultry Category							
First category wing	67	72	73	74			
First category %	77.00	80.50	82.02	82.22			
Second category wing	17	15	13	14			
The second category %	19.50	16.85	14.60	15.55			
Non-standard wing	3	2	3	2			
Non-standard %	3.50	2.65	3.38	2.23			

The study of the poultry meat category showed that the category I poultry meat in the fourth group was 82.12%, while the first category in the control was 77%, which is 5 percent lower. The meat of the first category was also 3% lower compared to the second and third groups by 1.0 and 2.0%.

As for non-standard poultry meat in the four groups is almost the same 2.2-3.5%. The chemical composition (water, crude protein, fat) is almost the same in all four groups. Almost identical and within the norm are some of the biochemical and morphological parameters of the blood which we have studied.

Results, Conclusion

Based on the studies conducted, the following conclusions can be made:

Synthesis conditions are established and glutamine acid methionine-containing and

molybdenum chelate compounds are synthesized

The composition of synthesized compounds determined by the microelement analysis method, and individuality - by melting temperature measurement and diffractogram method

Chelates are characterized by good solubility in water and dimethylformamide, and poor solubility in alcohol and acetone.

The degree of dissociation of compounds and the dissociation constants are determined by the method of conductometric research.

Thermal analysis has established that the thermal decomposition of compounds takes place in stages at the temperature range of 90-330°C in the following sequence: I- break-off of water molecules; IIoxidizing-glutamine acid (methionine) molecule; III- Molybdenum acid is decomposed and in all cases, the final product of decomposition is molybdenum oxide MO₃.

The use of molybdenum in chelate form during the broiler rearing period has had a positive effect on both the growth and maintenance of the broiler, feed conversion, slaughter output, and poultry meat category.

The optimal dose, as the experiment shows, is 100-150 mcg on 1 wing during the full rearing period. Accordingly, 1-1.5 grams should be added to 1 ton of feed.

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Review of the *Halyomorpha halys* (Stal, 1855) (Hemiptera: Heteroptera: Pentatomidae) in Georgia: Distribution, biology and management

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ABSTRACT

Halyomorpha halys (Stal, 1855) (Hemiptera: Heteroptera: Pentatomidae) invasion in Georgia territory first observed in 2015 year. In 2016-2019 an outbreak of *H. halys* resulting huge economic losses which negatively affected to the income of small-scale farmers as well as the Georgian economy. The article reviews the bioecological characteristics of the insect at various locations, such as in Georgia, other invaded areas and its natural distribution range of *H. halys*. This article describes the life history, food specialization, economic importance of *H. halys*. Also the recent results of studies on *H. halys* natural enemies, control tools and management strategies are incorporated to the article. In the face of climate change, the risks of insect outbreaks increase from year to year. Invasive agricultural pests such as *H. halys* pose a major threat to agriculture crop production and food security. To have a comprehensive information about *H. halys* has a huge importance to effectively plan and implement measures without or with minimal adverse environmental impact.

Key words: Halyomorpha halys, distribution, biology, natural enemies, management

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Introduction

The brown marmorated stink bug, Halyomorpha halys (Stål) (Hemiptera: Pentatomidae), is an invasive species native to China, Japan, Korea, and Taiwan [1]. Insect is highly polyphagous species, feeding on and damaging diverse plants, including field crops, vegetables, tree fruits, and ornamentals [2].

Synonymy

Halyomorpha halys (Stal, 1855) (Pentatoma halys Stål (1855), Poecilometis mistus Uhler, 1860; Dalpada brevis Walker, 1867; D. remota Walker, 1867). Distribution area: Anhui, Fujian, Guangdong, Guangxi, Guizhou, Hebei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Neu Monggol, Shaanxi. Shanxi, Sichuan, Taiwan, Xizang, Yunnan, Zhejiang. Also recorded from Korea and Japan [3].

This species has had a long and confusing history. It has appeared in the literature under

Halyomorpha halys and all three junior synonyms; in fact, it appears that many workers in Japan still refer to it as *H. mista*. It has also frequently been confused with *H. picus*, an Indian species. Josifov & Kerzhner (1978) [4] determined that only one species of *Halyomorpha* is present in eastern China, Japan, and Korea, and it is different from *H. picus*; the oldest available name is *H. halys* (Stal) [3].

Allochthonous distribution in the world

In the last 30 years, the species was detected in different parts of the world, mainly in North America and Europe (global distribution recently summarized by Leskey and Nielsen (2018) [5]. The first record of established population out of the native range dates in 1996 in Pennsylvania, USA, although prior to its establishment, *H. halys* was reported first time in 1973 [1]. This invasive species has spread across 43 states of the US and two provinces in Canada since it was first officially detected in Pennsylvania in 2001 [6].

From 2017, this invasive species has been detected in almost all states of USA, including Alaska and Hawaii, lacking only in Oklahoma and Louisiana [7, 8, 9]. In North America *H. halys* is reported also in southern Canada, where it was firstly intercepted in the Province of British Columbia in 1993, when a specimen was found in a shipment originating from Asia [10]. In South America *H. halys* is recorded from Chile, where it was intercepted for the first time in 2011 and later 2017 near Santiago [11] and finally, in the Caribbean basin countries were find.

In Asia, out of the native range, *H. halys* is quoted for India, reported in the 2014–2015 by Nikam & More (2016) [12]. However, this record is likely a misidentification with a different species [13].

In Pace Oceania some sporadic records are known from New Zealand, when it was introduce for the first time in 1999 [14], Australia, when it was introduce for the first time in 2005 [15], and Guam island, where a single specimen was collected in a hotel room in 2013 [16]. In Africa the species is not documented, but the record for Egypt of H. picus [17] could be a misidentification for *H. halys* according to Aukema et al. (2013) [18] and Hemala and Kment (2017)[19]. But in Japan and China, outbreaks there are not fixed. Most Complete data on the distribution of this species are given at EPPO Global Database (2022) [20].

Distribution in Europe

The other continent where *H. halys* has become a pest is Europe, where the oldest records date back to 2004: in that year *H. halys* was found in Liechtenstein [21] and Switzerland [22]. Subsequently, it colonized many Swiss territories [22,23] and some years later

it spread into neighbouring countries: in southern Germany in 2011 [24] and in France in 2012 [25,26, 27], also its in Corsica [7]. 2007 *H.halys* occurred in other European countries, in Italy [28,29] and in 2011 in Athens, Greece [30].

Until now, many countries in Europe have been added to the list of those where the *H.halys* occurs: in 2013 it was firstly recorded in Hungary [31] and in Krasnodar, Russia [32], in 2015 in Austria [33], Serbia [34], Romania [35], in 2016 in Spain [29], Slovakia [19], Bulgaria [36], and Georgia, Abkhazia [32], and in 2017 in Slovenia [9], Turkey [37] and Croatia [38]. Moreover, [39] reports that H. halys was founded twice in Great Britain, one in 2010 in London, in association with passenger luggage flown in from the USA, and the other in 2013 in North Yorkshire, associated with a consignment of stone imported from China.

Forecast of range expansion in the Russian Federation and neighboring countries [32] predicted a high probability that the *H.halyes* could spread in Eastern Europe between the 40th and 50th parallels or even up to the 60th parallel, at least populate the entire North Caucasus, the Rostov region, the south of the Volgograd region, as well as neighboring countries: Ukraine, Moldova, Bulgaria, southern Poland, also Armenia, Azerbaijan and Turkey. These findings are based on the work of [40], which used the Maximum Entropy methods (MaxEnt) and Genetic Algorithm for Rule Set Production (GARP) methods. According model of distribution of H,halys shows that more suitable areas for its distribution located between latitudes 30° and 50° and including parts of Europe, North America, Australia, the New Zealand, part of Africa (Fig. 1) [40].

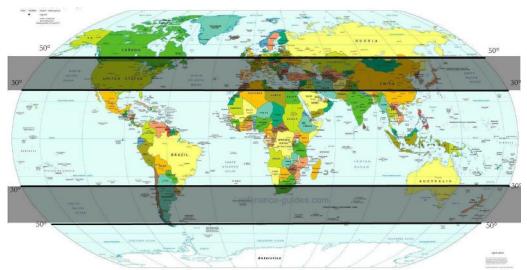


Fig. 1. Suitable areas for Halyomorpha halys distribution between latitudes 30° and 50° Source: Wine for Rookies, Inc

Distribution in Georgia

In Georgia, *Halyomorpha halys* (Hemiptera: Pentatomidae – formerly EPPO Alert List) was identified for the first time in October 2016. About its outbreak in Georgia was reported in the municipality of Khobi (Samegrelo-Zemo Svaneti region), as well as in Pitsunda (Abkhazia) [32]. However, it is noted that the presence of the bug had already been observed in 2015. This is the first time that *H. halys* is reported from Georgia [20].

It is not completely clear how the bug entered in Russia. There is an assumption [32] that this species was brought (probably from Italy) to one of the Russian Black Sea ports with planting material of ornamental plants for landscaping the facilities of the XXII Olympic Winter Games, similar to what happened in the case of the boxwood moth *Cydalima perspectalis* (Walker, 1859) (Lepidoptera, Pyraloidea: Crambidae) [41]. This assumption is also dictated by the fact that the same time, in neighboring countries (Moldova, Ukraine and Turkey) the *H.halys* was not found. And already from Russia the bug spread *to Abkhazia* and Georgia. Based on the available data, it can be assumed that the *H.halys* spread throughout the territory of the

Krasnodar Territory at a speed of 100–150 km per year [42].

Zhimerikin V.N and Guliy V.V. (2014) suggested that the Sochi City Administrative Okrug (territory of Greater Sochi) may be a place appearance of the *H.halys* in Russia. Its larvae were found in the city in August 2014 [44]. The author of the article studied 1 adult's specimen (female) with labeled "Russia, Sochi, Central District, 28.IX.2014. Koval A.G. leg". There are reports that this species appeared in the Sochi region no later than 2013 [32]. From the second half of 2015 mass reproduction of the bug began in the Sochi urban district, which led in 2016 to large losses in the harvest of fruit and subtropical crops [45].

In 2017-2018 for investigation of hazelnuts orchids the *H.halys* were detected in the Guria, Samegrelo, Adjarja and Imerety Regions of Western Georgia [46,47,48]. About distribution bug the same regions, were reported other scientist from Georgia as well [49-52]. At present Insect ivied and distribute in some municipals of Eastern Georgia, where hazelnut orchards are cultivated [52]. The distribution of *H.halys* in territory of Georgia given in Figure 2.

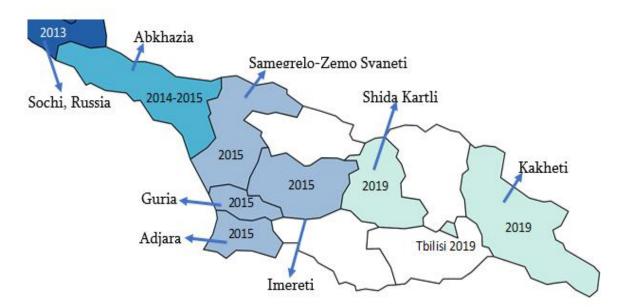


Fig. 2. Halyomoprha halys distribution in Georgia according years

The situation of *Halyomorpha halys* in Georgian neighbors countries can be described as follows: In Azerbaijan, it is distributed in the Cheki-Zakatala (East part border with Georgia), Lankaran and Absheron zones, where nut-fruits grow, especially walnuts (hazelnuts) and subtropical crops damages [53]; First record on the *H. halys* in Turkey

was 2017. This agricultural pest was detected in Kemalpaşa District of Artvin Province located in the Eastern Black Sea Region near the Georgian border [54]. However, information about this insect in Armenia no reported, only findings information as a hypothesis its distribution are given on the work of [40].

Life cycles

The brown marmorated stink bug, like all stink bugs, is a hemimetabolous insect and a multivoltine species, development from egg to adult takes approximately 40 to 60 days, depending on temperature and photoperiod. After hatching, first instar nymphs may aggregate around the egg clutch before molting and dispersing to feed. Adults can produce multiple egg clutches throughout their lifespan. Winter diapause is a crucial component of the brown marmorated stink bug life cycle. Bugs respond to shortening day length during fall by entering into diapause. During this period adult reproductive activity ceases as the stink bugs conserve resources to survive the winter. Only adults enter diapause and survive through the winter.increased temperatures and day length in the spring signal an end to the dormant period, and adult brown marmorated stink bugs will leave their overwintering sites in search of food. In warmer climates several generations per year are possible, though in most of its North American range the brown marmorated stink bug has one to two generations per year [55 - 61].

As a mention H. halys is a multivoltine species [62], in some geographical range, The life cycle is commonly characterized by one or two generations [61,58], but in Southern China four to six generations are assumed to occur [62]. Prereproductive adults overwinter in large number and they often use human houses as overwintering sites, with a documented case of 26,205 individuals in a single house during a 181-day study [63]. Adults entering houses are a strong nuisance not only for their abundance, but also for the unpleasant odor they emit when disturbed [64]. This behavior leads to a variety of pest impacts also for the human life [65], which add to the problems that *H. halys* causes to agricultural, horticultural and silvicultural hosts [10].

In Georgia, two generations of *H. halys* are commonly presented (Angelina), as a three generation reviewed [66] in Western Georgia (WG), that Black Sea region characterized by subtropical climate, with warm weather and humidity, which is favorable for this pest insect and help its develop and rapidly growing population.

H.halys biology involves pest development in three stages (egg, nymph and adult phase) and are following: (1). The pest overwinters in the adult (imago) phase; (2). Adults phase copulation begins

two weeks after diapause; (3). Eggs are laid by adults and continue at intervals throughout the life of the female to the end. There are observed pyramidal cluster mostly containing 28 eggs (average 26.27, st.dev- 4.20), but we are fined clusters with minimal number of eggs - 12, and maximunm - 32. On average 80.8 % of the laid eggs were hatched successfully. Under optimal conditions one female lays up to 400 eggs. Eggs are laid on the underside of the host plant leaf and they are white color; (4). The first nymphs hatch from eggs after 4-5 days; (5). The pest has 5 nymphal phases. Each lasts one week, at room temperature according to its change; (6). Adult and nymphs characherizaied with active movement and feeding. They are easy move on the vegetative parts of the plant, fly and feed by Fruits. The pest is characterized by the pierce-sucking mouthparts; (7). An adult insect infest almost all parts of the plant, especially the fruits. The damages part became necrosed, hardened and the crop loses its agricultural significance; (8).

There is two [66] or three [66]] Generations of *H. halys* in Georgia. The number of generations depends not only on the length of the day, but also on the temperature, because under suitable temperature conditions the development of the H. halys is faster [68], this process is also facilitated by the diversity of host plants [69] and air relative humidity [70]. Therefore in the humid subtropical regions of WG - Guria and Samegrelo, 2018 three generations were observed: the first generation egg-laying began in the early of May and lasted until the middle of May. Due to worming climate with annual average temperature 12 °C, (Climate Risk Country Profile: Georgia, 2021) and wide range of wild and cultivated host plants, H. halys populations develops within 32 days from egg to adult. The second generation emeges in the first decade of July and lasted until early August. Third generation occurs second decade of August and for mid of October they are entering to diapause.

Food specialization and harmful activity

The marble bug is a broad polyphage and feeds on flowers, stems, leaves and fruits of plants 49 families [14]. In the Sochi region and in Abkhazia 32 plant species from 16 families were recorded, on which the bug fed [71]. Of the cultivated plants, Rosaceae are the most harmful. Harm caused by the marble bug in the region of humid subtropics of Russia and Abkhazia, especially noticeable on fruit and

vegetable crops: on the surface of fruits and leaves of apple and pear trees in places of punctures necrosis, corking is formed, under the skin – dry cottony tissue, the taste of the fruit deteriorates, the surface becomes bumpy; on citrus and persimmon leads to underdevelopment and premature fall of the fruit; on grapes - the berries do not develop and fall off; on hazelnuts, it damages nuts at the stage of milky-wax ripeness, leading to the cessation of the development of the kernel; on corn grains do not develop. Damage can be aggravated by secondary infections. So, for example, on pepper and tomato fruit rot develops at the puncture sites [6,45]. Bugs also can transmit phytoplasmoses causes pathogen [72].

In a review of the Asian literature [58] revealed in native range 106 host plants distributed in 45 families, while [68] reported 51 hosts in 32 families in Europe and [73] quoted 73 species of plants ranging from annual crops to landscape trees only in the state of Pennsylvania. Now, over 251 species of host plants are cited in literature for this bug [74] and it is considered a severe agricultural and horticultural pest [7]. Feeding may occur on leaves, shoots, stems and even through the bark of trees such as maple and catalpa [6]. However, both nymphs and adults preferentially feed on developing and ripe fruits and seeds of their host plant [75]. This mode of feeding, and preference for fruits, directly leads to economic damage to a wide range of crops.

In Georgia 2018-2021 years, during observation twelve plants species as host of *H. halys* were identified: Eriobotrya japonica, Laurus nobilis, Actinidia sp., Agave sp., Solenostemon sp., Pueraria sp., Rubus canescens, Sambucus ebulus, Convolvulus sp., Robinia pseudoacacia, Tradescantia sp., Pteris cretica. They are not included as host plants of this insect in CABI, EPPO, and official lists of the Ministry of Environment Protection and Agriculture of Georgia [46].

In its native range, it is considered an occasional pest of fruit trees and soybean, Glycine max (L.) Merr. (Fabales: Fabaceae), as well as a nuisance pest during the winter [76 - 85].

Insect damages wild, ornamental and cultivated plants. They manly feed on pome, stone, nut, legume fruits. The signs of *H. halys* feeding range from the multiple punctures in the hull (endocarp) to the formation of the necrotic tissues on the shell (endocarp), hull (exocarp and pericarp) and the kernel (endosperm) of the fruit [86]. Damaged fruits have necrotic spots or blotches, grooves and brownish discolorations. In Asia, *H. halys* is

considered as causing significant damage to soybean and various horticultural crops. In Japan, apple crops have increasingly been damaged by *H. halys*. Forest trees are also known hosts of H. halys. However, in Japan H. halys is considered as a pest in nurseries producing seeds of cedar and cypress because it can feed on cones. In the USA, damage caused by H. halys was initially reported in suburban or urban environments on woody ornamentals (e.g. Buddleia davidii, Paulownia tomentosa) and backyard peach and pear trees. However in 2006, commercial fruit growers started to report damage in apple and pear orchards in eastern Pennsylvania and western New Jersey. In Pennsylvania, high populations were also found in soybean crops but without significant damage. H. halys is considered as a vector of Paulownia witches' broom phytoplasma in Asia.

In addition to plant damage, *H. halys* can be a nuisance to humans because at the end of autumn, adults can aggregate in buildings and houses (on walls, window and door frames) seeking overwintering sites. When disturbed or crushed they discharge a characteristic pungent odour (unpleasant and long lasting!). In the USA, many homeowners are complaining about this nuisance.

Damage and Economic Importance

Many studies have shown that stink bugs in the family Pentatomidae can be serious economic pests of food crops and ornamental plants around the world [87,88]. Worldwide, this family contains almost 900 genera and around 5000 species [89]. Many pentatomids cause significant damage to hazelnut crops in Europe, Turkey and Georgia [90]. In particular, stink bug pests of cultivated hazelnuts (Corylus avel-lana L., Fagales: Corylaceae) occur in the leading commercial hazelnut producing countries of Turkey [91] and Italy [92]. Studies in Turkey report feeding damage to hazelnut kernels by Palomena prasina L. (Hemiptera: Pentato-midae) in the form of kernel abortion, malformation, and the occurrence of dry, necrotic tissue [93]. According [94], hazelnut in northwestern Italy was damaged by seven species of Pentatomidae.

In Asia *H. halys* causes significant damage to many economically important crops In Japan, outbreak populations of *H. halys* on apple [95-98], pear, plum, satsuma mandarin, and grape [95] have been reported, with damage characteristics and levels varying among crops. In 2010, high densities of *H. halys* caused as much as 100%

crop loss in some apple and peach orchards in the Eastern USA [5]. In Italy some early maturing pear cultivars damage at harvest reached more than 50% [99] Economic damage on pepper crops has been reported in Europe from the Canton Aargau in Switzerland [100], In 2016 52.7–68.6 million US dollars losses in hazelnut crops which caused by *H. halys* in Georgia [101].

In Georgia, Due to lack of specific natural enemies, high reproduction ability, wide host range, and favorable climate conditions, effective overwintering strategies, increased population rate of *H. halys* that caused huge economic losses in agricultural crop production [102]. In 2016 The most affected was hazelnut production were economical loss reached 60 milion dollars [101] . Although In 2017, compared to 2016, revenue from hazelnut exports fell by \$ 54 million [103]. In 2019, the fight against *H. halys* was declared successful [104], which led to an increase in hazelnut production [105].

Natural enemies

Brown marmorated stink bug parasites or predators, entomopathogens have the potential to provide landscape-scale control of this pest in the future. Since the establishment of the, *H. halys* in North America and Europe, there has been a large, multi-group effort to characterize the composition and impact of the indigenous community of arthropod natural enemies attacking this invasive pest.

Native predators

The list of native natural enemies that attack brown marmorated stink bug includes other species of insects, spiders, and even some birds and mammals. However, insects and spiders are largely recognized as the most important group of natural enemies of BMSB [106].

Wide variety of generalist predators that consume H.yalys eggs have Identified in the USA. The list includes certain species of crickets, katydids, ground beetles, lady beetles, earwigs, ants, assassin bugs, mantids, and jumping spiders, as well as less familiar insects such as minute pirate bugs, lacewings, and damsel bugs [107].

The community of indigenous generalist predators consuming *H. halys* eggs is very diverse, made up of many species with a variety of modes of feeding. Morrison et al. (2016) [108] identified four distinct predation "syndromes" on H. halys eggs

using laboratory observations of over 25 predator taxa: (1) complete chewing—eggs completely removed from substrate; (2) incomplete chewing—egg shell debris from predated eggs remains on substrate; (3) stylet sucking—presence of a feeding sheath in eggs drained of their contents; and (4) punctured sucking—a hole or slit in hollowed-out eggs. In the laboratory, the most efficient predators were katydids (Orthoptera: Tettigoniidae), ground beetles (Coleoptera: Carabidae), crickets (Orthoptera: Gryllidae), earwigs (Dermaptera: Forficulidae), and jumping spiders (Araneae: Salticidae) [109]

Predators attacking *H. halys* adults and nymphs in Europe and North America have not been extensively studied. In one study of the nest-provisioning wasp *Bicyrtes quadrifasciata* (Say) (Hymenoptera: Crabronidae) in the northeastern USA, H. halys nymphs made up 96% of the prey provided to developing offspring [110]. Another crabronid wasp, *Astata unicolor* Say, was also observed preying on *H. halys* nymphs. Jones (2013) [111] commonly observed predation of H. halys adults and nymphs by the wheel bug Arilus cristatus (L.) (Hemiptera: Reduviidae) in Maryland, USA. Predation of adult H. halys by praying mantids (Mantodea: Mantidae) has also been observed on a number of occasions in the USA.

Interestingly, only one unpublished study has gathered some information on the consumption of newly emerged (1st instar) H. halys nymphs, which are clustered on egg masses for several days and potentially vulnerable as they are relatively immobile and soft-bodied. That study observed the highest predation of freshly emerged first instar nymphs in the laboratory by field-collected Carabidae (89% of nymphs emerged were eaten), predatory Pentatomidae (88%), Salticidae (35%), and Reduviidae (26%;) [112].

According to Kharabadze et al., (2022) [113] *Hierodula transcaucasica* Brunner von Wattenwyl, 1878 were observed as a predator of *H.halys* in Georgia. Predation of the adults and nymphs of *H. transcaucasica* was documented after they underwent starvation periods. The 3rd instar nymph of *H. transcaucasica* preyed on the 1st instar *H. halys* nymphs, while adult *H. transcaucasica* attacked adult of *H. halys*. A maximum number of *H. halys* (7 insect) were eaten by an adult *H. transcaucasica* on the first day, and in this case, the same number of nymphs (7 insects) were observed within the first hours of the experiment.

Parasitoids

Since the impact of native natural enemies on invasive *H. halys* populations in Europe and North America is generally low, *H. halys* was identified as a promising target for classical biological control. Surveys for natural enemies that have co-evolved with *H. halys* in its native range revealed that it is mostly attacked by egg parasitoids, among which the samurai wasp, *Trissolcus japonicus*, was identified as the most promising candidate for classical biological control.

In China, *Trissolcus japonicus*,[114] a parasitoid wasp species in the family Scelionidae, is a primary predator [115]. In the United States, Europe, and New Zealand, *Trissolcus japonicus* is a focus of biological control programs against *H.halys*. in 2014, two adventive populations were found in the United States during surveys to identify which North American parasitoids might be attacking brown marmorated stink bug.[116,117] Subsequent genetic testing showed these wild populations were self-introduced: they were not related to each other, or to a laboratory strain being studied in quarantine. [118 - 121] An adventive European population was discovered during similar surveys in Switzerland in 2017 [122].

Trissolcus japonicus is a tiny wasp that parasitizes the eggs of various stink bug species. It was first collected from China and brought back to quarantine facilities in the US for evaluation, as a potential biological control agent. Host-specific tests have indicated that *T. japonicus* prefers to parasitize *H.halys* eggs over eggs of other stink bug species.

Abram et al., (2017) [112] reported that *H. halys* and other stink bug species data from the USA supports the hypothesis that the relative prevalence of different parasitoid species associated with *H. halys* eggs is habitat-dependent [123,124].

Three principal groups of hymenopteran parasitoids attack *H. halys* eggs in invaded areas of North America and Europe: Scelionidae (Telenomus, Trissolcus, and Gryon spp.), Eupelmidae (Anastatus spp.), and Encyrtidae (Ooencyrtus spp.). The host range of the scelionids were detected, especially Telenomus (podisi group) and Trissolcus spp., tends to be restricted to stink bugs (Hemiptera: Pentatomidae) [125-129].

Scelionid parasitoids of stink bug eggs have stereotyped behavior, remaining on the patch for several hours after oviposition and engaging in aggressive inter- and intraspecific contests with other parasitoids [130]). Eupelmids and encyrtids found attacking H. halys are likely to be generalists that attack multiple families of insect hosts and some species are facultative hyperparasitoids [131,132]

According to Japoshvili et al.(2021) [133], five species of *Trissolcus* Ashmead (Hymenoptera: Scelionidae), which are known parasitoids of Pentatomidae, were identifed. Four of these (*T. belenus* (Walker), *T. colemani* (Crawford), *T. scutellaris* (Thomson)) and *T. semistriatus* (Nees) are documented for the first time from Georgia, and two are new records for the Caucasus region. Also, *Anastatus bifasciatus* was recorded from Georgia as a *H. halys* eggs parasitoid [134] and as a native species considered for potential biocontrol in Europe [135].

Entomopathogens

Entomopathogenic microorganisms are one of the promising naturel enemies for control many invertebrate pest. In this case, less information documented about pathogens of *H.halys*. First description a unique microsporidian species that infects the green stink bug, *Chinavia hilaris* and the brown marmorated stink bug - Halyomorpha halys first were observied in US. this microsporidium belong in the genus Nosema, which historically has been characterized by diplokaryotic life stages. This microsporidium is apparently Holarctic in distribution. Nosema maddoxi is native to North America and has also been found in China and South Korea; in North America it infects native stink bugs and *H. halys*.

Morphological, ultrastructural, and ecological features of the microsporidium, together with a molecular phylogeny, establish a new species named *Nosema maddoxi* sp. nov. [136].

A microsporidian pathogen discovered in Georgian of *H. Halys* has been identified as *Nosema maddoxi*. Investigations were carried out during different seasons in three regions of West Georgia in 2018–2019. [137] the highest prevalence of *N. maddoxi* was detected among overwintered adults collected in May in the Guria region. Molecular study was confirmed that this specie is Nosema *madoxi* [138].

First report on entomopathogenic fungi species, that infects *H. halys* were observed in Guria and Samegrelo region of Western

Georgia. In different *H.halys* populations, adults developed mycosis symptoms on the body were observed. Three isolates of entomopathogenic fungus *Beauveria bassiana* and one of *Isaria fumosorosea* were identified [48]. Isolated species were studded in morphological and carried out in molecular identification [139].

Management and control

Current management tactics for *H. halys* mostly rely on insecticide applications [6, 140]. As indigenous parasitoids and predators adapt to *H. halys* and exotic parasitoids continue to spread and establish, biological control is expected to become an increasingly important component of integrated pest management programs.

At present, there are no published studies of how landscape factors or proposed alternative onfarm management practices (e.g., attractand-kill—[141]; trap crops—[142]; border and alternate-row spraying—[143], [144] insecticide-incorporated nets—[140]) influence indigenous natural enemies and their impact H. halys population growth. To assess the effect of these pest management practices on biological control services, future studies will need to integrate accurate measurements of population-level impact with chemical, behavioral, and invasive species ecology.

Numerous methods have been used to demonstrate the relative effectiveness of a broad range of insecticides against H. halys adults and nymphs, including treated glass surfaces [143,145,146], direct-contact topical applications (G. K., unpublished data), bean dip feeding bioassays [147], and field efficacy trials [148,149,150,151]. Active ingredients that have been most effective include several pyrethroids (bifenthrin, permethrin, fenpropathrin, and beta-cyfluthrin), neonicotinoids (dinotefuran, clothianidin, and thiamethoxam,), (methomyl carbamates and oxamyl), organophosphate acephate, and the organochlorine endosulfan. Unfortunately, these insecticides are generally broad-spectrum in their activity; they can be hard on natural enemy populations and quite disruptive to integrated pest management programs [152].

Hazelnuts orchards growers in the Black Sea region, Colchis Lowland of WG, insecticide applications were used. USAID is helping Georgia combat the country's stick bug infestation problems and offers \$3.5.[49]. State control program against

H. halys were obtained since Nowember 2016 In Georgia. Within this program about 110 000 ha of land were treated by pyrethroid insecticides (Bifetrin) per year. Infested plots are treated by thermal fog - with low-volume spraying technology. In 2017, 58, 416, 8 ha of land were treated, In 2018, 790 000 ha and in 2021 a total area of 37,236 hectares has been treated (https://agenda.ge/en/news/2021/2359)

Also, 21 000 pheromone traps (Tracky), were placed for the monitoring purposes, 100 000 phereomones placed for the "attract and kill" stations in the external perimeters of the forests and villages through the country. Large scale farmers were supplied with pyrethroid (Bifetrin) insecticides. Information campaign is carried out systematically, brochures are printed, video clips are made. A hotline has been opened which can be use for getting comprehensive information and consultation around Halyomorpha halys. In pursuit of the BMSB monitoring, 8000 pheromone traps were placed throughout the country and 28,818 'attract and kill stations and 5,754 pheromone traps were been installed" (https://agenda.ge/en/ news/2021/2359). Also about), Bioecological features H.halys and it control mechanisms in Adjara Region of WG, use pheromone traps for the monitoring were report in the publication of Dumbadze and all (2019) [51].

According Burjanadze et al.(2021) [153] against *H. halys* local production of mycopesticiede, trade mark- Bover-GeTM, were tested in laboratory and field condition. It was registered by National food agency (NFA) of Georgia as a biopesticides, which are based on local strain of entomopathogenic fungus *Beauveria bassiana*, isolated from soil of high mountain of Caucasus region. Bover–Ge were tested at a concentration of 1×10⁸ conidia/ml against adults, where in laboratory 93.3%, in field 87 % and in migration stage 64% mortality were observed.

The potential of native entomopathogenic nematodes: *Heterorhabditis bacteriophora* (HRB, GEO) and Steinernema borjomiense, *H. bacteriophora* (HRB, IT) and S. apuliae were evaluated agins adults *H.halys* in laboratory, where effectiveness from H. *bacteriophora* (GEO, IT) 53-95.3%, from S. *borjomiense* and *S. apuliae* 40-60% were observed. The present study provides further insights in selection of promising EPN strains to be used against *H.halys* [48].

Conclusion

Halyomorpha halys invaded Georgia in 2015 and by 2016 the mass spread of the pest caused epizootic, huge economical, ecological losses. In 2019, the epizootic outbreak of Halyomorpha halys was declared eliminated. Success was achieved through using agro-technical measures, chemical pesticides and pheromones. Scientific studies revealed that local natural enemies predators, parasitoids and pathogenic microorganisms have co-evolved with H. halys. Also, testing local isolates of parasitic nematodes and entomopathogenic fungi proved their effectiveness as a control tool against H. halys.

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