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BIOLOGICAL CONTRA CHEMICAL DIVERSITY AND THEIR PRACTICAL, INSECTICIDAL ASPECTS IN LICHENOLOGY

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BACKGROUND AND AIMS OF THE INVESTIGATION

A symbiotic relationship between fungi (mycobiont) and algae and/or cyanobacteria (photobiont) constitutes a lichen, though this definition has been challenged due to limited knowledge on the role of other microorganisms (HAWKSWORTH & GRUBE 2020, SANDERS 2024). The relationship forms unique structures different from the symbiotic partners and the mycobiont produces special lichen secondary metabolites (LSMs) with biological activities (STOCKER-WÖRGÖTTER 2008, ELIX 2022), that determined the main subject of my study.

The LSMs (mainly depsides, depsidones, and dibenzofurans) have, among other roles, a photoprotection role and antiherbivore effect (MCEVOY et al. 2006, BECKETT et al. 2021, NIMIS & SKERT 2006). Their insecticide potential was also investigated (MOLNÁR & FARKAS 2010, BHATTACHARYYA et al. 2016). The LSM usnic acid exists in two optical isomers (enantiomers) with different biological activities, as it was found in *Cladonia foliacea* and *Ramalina farinacea*, exhibiting strong larvicidal effects against *Culex pipiens* larvae (CETIN et al. 2008). In the initial stages of my PhD studies, I reviewed existing literature on the application of lichens and LSMs as insecticides and highlighted a research gap in their potential use as toxic sugar bait in mosquito control (MUHORO & FARKAS 2021). The most effective and widely applied LSMs could be investigated for their insecticidal potential in bioassay experiments in Kenya to control *Anopheles gambiae.*

Malaria remains a significant health matter, with 249 million cases reported in 2022 (WHO 2024). The affected population were mainly in African regions, where 95% of the malaria-related deaths occur. Among them 80% are children (WHO 2024). The primary vectors of *Plasmodium falciparum* in Western Kenya are *An. gambiae* (s.s.), *An. arabiensis* and *An. funestus* (ROBI et al. 2010, STEVENSON et al. 2012, WIEBE et al. 2017). Efforts in the protection against malaria infection include minimizing mosquito bites through tools like insecticide-treated nets, indoor spraying, larvicides, and genetically modified mosquitoes (TIZIFA et al. 2018, KARUNARATNE & SURENDRAN 2022). A novel method, that targets indoor resting mosquitoes using insecticide-treated wall lining nets containing deltamethrin, has been shown to significantly reduce indoor resting mosquitoes in Budalangi in western Kenya (MUHORO 2013). However, despite the application of various methods using synthetic chemicals, there are several challenges such as mosquitoes developing resistance to insecticides. Human behaviours such as non-intended and improper use of bed nets are a major challenge to malaria eradication in Western Kenya (MACHANI et al. 2020, ODERO et al. 2024).

However, Kenya and other African countries should remain hopeful in the fight against malaria and apply the strategies used by other countries that have achieved malaria-free status (BADMOS et al. 2021). Focusing on alternative biopesticides that have shown to be insecticidal may offer a considerable degree of success in vector control. Lichens are known to possess biological active secondary metabolites that have insecticidal potential against mosquitoes and other agricultural pests such as weevils (VINAYAKA et al. 2009, DA SILVA et al. 2023). LSMs are attractive candidates for biopesticide development since they are less toxic to the environment and to nontarget organisms (HAGER et al. 2008, MUHORO & FARKAS 2021).

The knowledge of lichens in Africa is limited, however, there is evidence of increasing knowledge from several publications after the work of SWINSCOW & KROG (1988) by the use of morphological, chemical and molecular genetic characteristics (ALSTRUP & APTROOT 2005, ALSTRUP & CHRISTENSEN 2006, YESHITELA et al. 2009, FARKAS & FLAKUS 2015, BJELLAND et al. 2017, KANTELINEN et al. 2021, FRYDAY et al. 2022, KAASALAINEN et al. 2023, KIRIKA et al. 2016a, 2016b, 2017). Therefore, the identification key of the parmelioid group would be necessary to revise since it contains many lichen species with potential bioactive compounds.

The most widely studied LSM is the usnic acid (UA). It has been found to possess a range of biological activities including antimicrobial, larvicidal, and anticancer properties (DIEU et al. 2020, GALANTY et al. 2021, MUHORO & FARKAS 2021, KULINOWSKA et al. 2023). Two enantiomers of UA exist in lichens, (+)-UA and (-)-UA and their biological activities also vary (GALANTY et al. 2019).

Flavoparmelia caperata and *Cladonia foliacea*, are known to produce specific enantiomers of UA, with *F. caperata* exclusively producing (+)-UA and *C. foliacea* producing (-)-UA only and another major LSM, fumarprotocetratic acid (FA) (SMITH et al. 2009, WIRTH et al. 2013, CAVALLORO et al. 2021). It is known that factors like temperature, radiation, and humidity, influence the production of UA in these lichen species since they are found in different climatic and geographical areas (MCEVOY et al. 2006, VERES et al. 2020, 2022).

UA's potential as an insecticide constitutes the lichenological aspects of its application to control *Anopheles gambiae* in this dissertation. According to the previous studies (-)-UA might be even more potent (CETIN *et al.* 2008), hence bioassay testing on *An. gambiae* with both (+)-UA and (-)-UA, furthermore, with extracts containing (-)-UA for malaria vector control strategies as toxic sugar bait are considered to be promising.

The aim of my thesis work is therefore

- to study the diversity of lichens with insecticidal potential, their lichen secondary metabolites, and the amount and chiral property of usnic acid (UA) in *Cladonia foliacea* and *Flavoparmelia caperata*,
- to determine the insecticidal potential of the pure usnic acid and the acetone crude extract of *C. foliacea* as an oral pesticide against *An. gambiae* mosquitoes.

In order to achieve these, my further specific aims were

- to review the current literature on lichens and insecticidal activities of their LSMs with specific attention to the life stages of mosquitoes and their role in malaria control,
- to study the biological and chemical diversity of LSM-rich lichen taxa of East Africa and compile a revised identification key of the lichen species of the parmelioid clade in Kenya to promote their collection, research and future studies of their biological role and application,
- to confirm the chiral property (+) and determine the amount of usnic acid in *F. caperata* (Parmeliaceae, lichenized Ascomycota) from samples collected in Kenya and Europe,
- to confirm the chiral property (-) and determine the amount of usnic acid and fumarprotocetraric acid (FA) in *C. foliacea* from Central and Southern Europe,
- to determine the insecticidal potential of (+**)-**usnic acid as an oral pesticide against *Anopheles gambiae* mosquitoes,
- to determine the insecticidal potential of (-)-usnic acid and

fumarprotocetraric acid containing acetone extract of *C. foliacea* as an oral pesticide against *Anopheles gambiae* mosquitoes.

MATERIALS AND METHODS

A review of current English language literature on LSMs as insecticides (MUHORO & FARKAS 2021) followed the guidelines by KHAN et al. (2003) using the following databases and keywords, databases: Google Scholar, PubMed, Recent literature on lichens, Scopus and Web of Science; keywords: “lichen secondary metabolites” AND “insect vectors” AND “human diseases” AND (“insecticidal” OR “bioassay” OR, “bioactive”) and (“insect vectors of parasitic” AND “human” AND “protozoa” AND “diseases”). Variables like lichen species and the target vector/ protozoa, dosage and mortality rate were documented to be reviewed.

Literature on parmelioid clade was obtained from the book “Macrolichens of East Africa” and other published literature (SWINSCOW & KROG 1988, KIRIKA et al. 2016a, 2016b, 2017).

The lichen specimens used for illustrations, morphological and chemical studies and for bioassay tests were deposited in herbarium VBI (THIERS 2024, continuously updated) at the Institute of Ecology and Botany of HUN-REN CER, (Vácrátót, Hungary).

Several lichen specimens collected from various countries were studied by light microscopes (Nikon SMZ18, Olympus SZX7) and their LSMs by spot tests by ORANGE et al (2010) and high-performance thin layer chromatography (HPTLC) according to ARUP et al. (1993) and MOLNÁR & FARKAS (2011).

Flavoparmelia caperata samples (30) were collected in Hungary (by E. Farkas, L. Lőkös, A. M. Muhoro, N. Varga), Serbia (by L. Lőkös), Kenya

(P. M. Kirika, H.T. Lumbsch, G. Mugambi, A. M. Muhoro) and Tanzania (by E. Knox, T. Pócs) between 24 October 1987 and 5 September 2022 (**Fig. 1**).

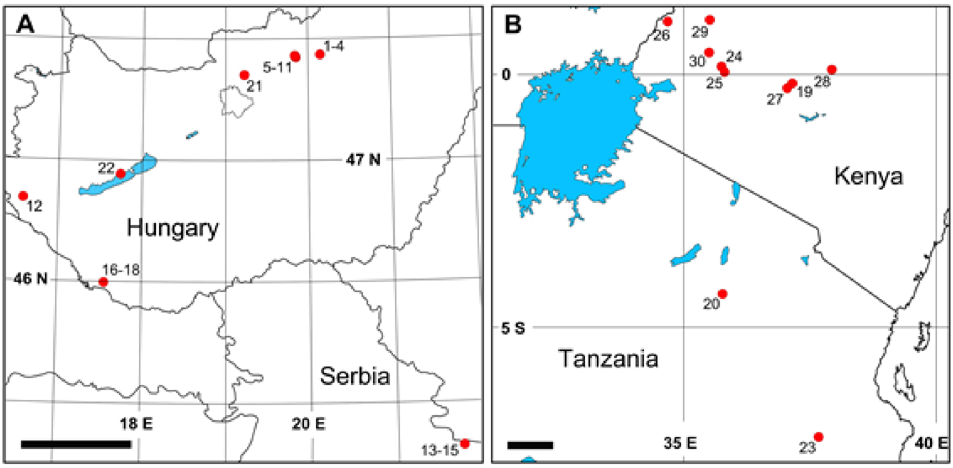

Fig.1. Collecting sites of the investigated *Flavoparmelia caperata* samples. **A**, in Hungary and Serbia; **B**, in Kenya and Tanzania. Scale bars = 100 km.(FARKAS et al. 2024a).

Cladonia foliacea samples (29) from Hungary, Albania and North Macedonia were used for chiral chromatography and quantitative HPLC-PDA analysis. They were identified by E. Farkas, L. Lőkös and N. Varga.

Thalli of *C. foliacea* were collected from Hungary [Pest County, Vácrátót, Tece, along the ’red line’ tourist route (Ág-dűlő), in open sandy grassland from the soil. Lat.: 47.702358° N; Long.: 19.224312° E] for bioassay studies.

Distribution maps indicating the main sampling points of *C. foliacea* and *F. caperata* were prepared using Quantum Geographic Information System (QGIS) 3.18.2 ‘Zürich’ version 2020.

To determine the amount of UA, high-performance liquid chromatography (HPLC, Alliance e2695, Waters Corporation, Milford, MA, United States) system, with a photodiode array detector (PDA, 2998, Waters Corporation, Milford, MA, United States) was used as described by JI &

KHAN (2005) by K. Szabó in Centre for Ecological Research, Vácrátót. UA enantiomers were determined according to the method described by XU et al. (2022) in University of Iceland (Faculty of Pharmaceutical sciences, Reykjavik, Iceland).

C. foliacea thalli (**Fig. 2**) were extracted for bioassay studies following the method described by MOHAMMADI et al. (2020) at Egerton University (Department of Biochemistry and Molecular Biology, Egerton, Kenya).

Fig. 2. The lichen *Cladonia foliacea* extracted for applying in sugar bait (photo E. É. Farkas).

Bioassay laboratory experimental tests were worked out (protocol number SERU04–06–423/4610) and conducted at Kenya Medical Research Institute (KEMRI-CDC) laboratories in Kenya according to ALLAN (2011). The (+)-usnic acid (Phytolab GmbH & Co. KG, Vestenbergsgreuth, Germany) and the lichen extract were dissolved in acetone to make different concentrations. Male and female *An. gambiae* mosquito (Kisumu reference laboratory strain) were denied sugar but provided with water (**Fig. 3–4**). Knock-down effect was determined after 4 hours of exposure and mortality was recorded in intervals of 24 hours for up to 72 hours. Estimated marginal means (EMMs) were calculated to provide the average total mortality adjusted for other covariates in the model. Visualization of results was completed using the ggplot2 R package (v3.5.1; WICKHAM 2016). All statistical analyses were conducted in R Statistical Software (v4.4.0; R CORE TEAM 2024). The estimated marginal means (EMMs) of mortality for various concentration levels and exposure times were analyzed.

Fig. 3. *Anopheles gambiae* mosquito (photo J.J. Kosgei)

Fig. 4. Membrane feeding system (photo A.A. Muhoro)

RESULTS AND DISCUSSION

The review on insecticidal and antiprotozoal activities of lichens and lichen secondary metabolites confirmed that 7 lichen secondary metabolites from 32 lichen species (MUHORO & FARKAS 2021) were characterised with insecticidal or antiprotozoal activity: 1′chloropannarin, evernic acid, gyrophoric acid, psoromic acid, pannarin, usnic acid, and vulpic acid. The mosquito species belonging to *Aedes, Anopheles* and *Culex* were susceptible to LSMs from 57 lichen species. Notably larval stage of *A. aegypti*, *An. stephensi*, *C. pipiens* and *C. quinquefasciatu*s were mainly investigated. No studies investigated the susceptibility of adult stages of the *An. gambiae* to LSMs or their hatching inhibition. 2^{nd}, 3^{rd} and 4^{th} larval stages of mosquitoes were investigated (VINAYAKA et al. 2009, KHADER et al. 2018, CETIN et al. 2008).

The species-rich lichen family Parmeliaceae is widely distributed in the Southern Hemisphere and its largest clade, the parmelioid clade, contains about one tenth of the lichen species known worldwide (with c. 1800 spp. – KIRK et al. 2008, THELL et al. 2012). The group is rich in LSMs with various bioactive and other potential roles. However, identification of its species was hardly possible by the key of SWINSCOW & KROG (1988) due to the considerable changes during decades after its publication, and preparation of a revised key was necessary (FARKAS & MUHORO 2022). The following morphological characteristics were checked among the revised parmelioid species: growth form – foliose, not umbilicate, thallus corticate above and below, adnate or loosely attached to substrate, rhizines – present, medulla – solid, colour – grey, yellowish green or brownish, fruitbody if present – apothecium with thalline exciple, ascospores – simple, pycnida – laminal.

The 178 species (all containing green alga photobiont) after nomenclatural revision belong to the genera *Bulborrhizina* (1), *Bulbothrix* (9), *Canoparmelia* (9), *Cetrelia* (1), *Crespoa* (1), *Flavoparmelia* (4), *Flavopunctelia* (2), *Hypotrachyna* (37), *Melanelixia* (1), *Myelochroa* (1), *Parmelia* (2), *Parmelinella* (1), *Parmotrema* (64), *Pseudoparmelia* (2), *Punctelia* (9), *Relicina* (4), *Remototrachyna* (1) and *Xanthoparmelia* (29). The dichotomous main key leads to species where the genus has only a small number of representatives (maximum 4 species), but otherwise to genera. Larger genera are treated separately after the main key. *Bulborrhizina* (1) is treated in the generic key (*Bulbothrix* s. lat.) together with *Bulbothrix* (9); *Canoparmelia* (9) and *Pseudoparmelia* (2) are also treated in the same key.

New distribution records of lichens were identified, from Kenya: *Usnea abissinica, U. sanguinea,* and from Tanzania: *Bulbothrix kenyana,* *Chrysothrix xanthina, Lobaria discolor, Parmotrema durumae* and *P. taitae.* Lichenicolous fungi new to Kenya and East Africa were also detected (on host lichens in brackets): *Didymocyrtis cf. melanelixiae* (on *Parmotrema austrosinense*), *Lichenoconium erodens* (on *P. austrosinense*), and *Spirographa lichenicola* (on *P. austrosinense* and *P. reticulatum*) (FARKAS et al. 2023).

European and African *F. caperata* specimens when analysed using chromatographic methods (chiral chromatography and HPLC-PDA) indicate that only (+)-UA was confirmed in specimens and the amount ranged from 5.08 to 26.43 mg/g dry wt in European samples (12) and 20.27 mg/g dry wt in a sample from Kenya (FARKAS et al. 2024a). The comparison between continents did not result in significant differences ($p = 0.91$). This could be due to similar microclimatic conditions of the habitats (within macroclimatically different sites) (MOREAU 1938, HEILMANN-CLAUSEN et al. 2014) that are probably consistent with the specific niche requirements of the species. However, further investigation using large sample sizes fom wider geographical regions may provide more details on the variation of UA in *F. caperata*.

C. foliacea lichen samples obtained from Central Europe were analysed to detect and quantify fumarprotocetraric acid (FA) and (-)-usnic acid (UA) (FARKAS et al. 2024b). The two LSMs were detected in all samples. The content of FA (1.44–9.87 mg/g dry wt) was lower than that of (-)-UA (6.88 to 34.27 mg/g) lichen dry wt. This study has provided evidence that (+)-UA is not present in detectable amounts in *C. foliacea* and further supported results of previous studies (CAVALLORO et al. 2021).

Toxic sugar bait containing (+)-UA as an ingredient killed both male and female *An. gambiae* at different concentrations and exposure times (**Fig. 5**), a high mortality rate (50%) was observed at (15 mg/ml) after 4 hours of exposure, however, mortality declined with prolonged exposure up to 72 hours (MUHORO et al. 2024b). Lower concentrations (5 and 10 mg/ml) caused significant mortality over 24 hours, therefore at low concentrations, the target mosquitoes would be susceptible when exposure time is increased. Higher mortality was reached among males than females at 48 and 72 hours exposure times. It is to be noted that in other related study, short exposure time (24h) using 4% boric acid caused 100% mortality of adult *Aedes aegypti* and *An. stephensi* (KUMAR et al. 2022).

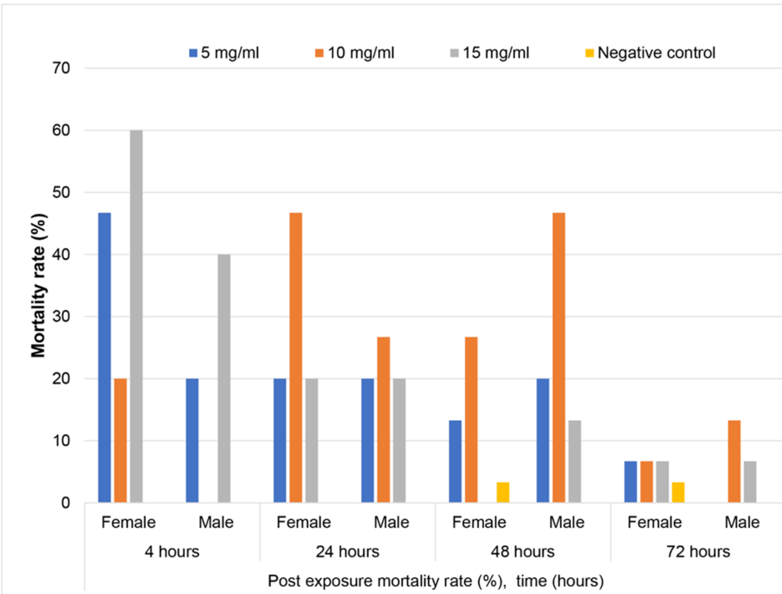

Fig. 5. Mortality (%) of both male and female *Anopheles gambiae* after oral ingestion of (+)-UA.

Extract of *C. foliacea* were also investigated (MUHORO et al 2024a), however, its toxicity against *An. gambiae* was associated with higher concentrations compared to (+)-UA (**Fig. 6**). The sex of the mosquito did not influence mortality, however, concentration and exposure time have statistically significant effects on the total mortality of adult *An. gambiae*, indicating that mortality levels vary significantly with increasing concentration and exposure duration. A significantly higher effect was observed at 50 mg/ml compared to controls. Equally, increasing the exposure time at concentrations between 10 to 30 mg/ml has no significant effect on mortality. Since both males and females ingested the sugar bait containing substances known to have an antiherbivory effect, therefore 10% sugar solution could stimulate and sustain feeding (**Fig. 6**). In agreement with the current results, oral toxicity of extracts of *C. foliacea* on *Sitophilus granaries* has also demonstrated dose- and time-dependent response mortality effects where high concentration and longer exposure time resulted in a significantly higher mortality rate (EMSEN et al. 2012).

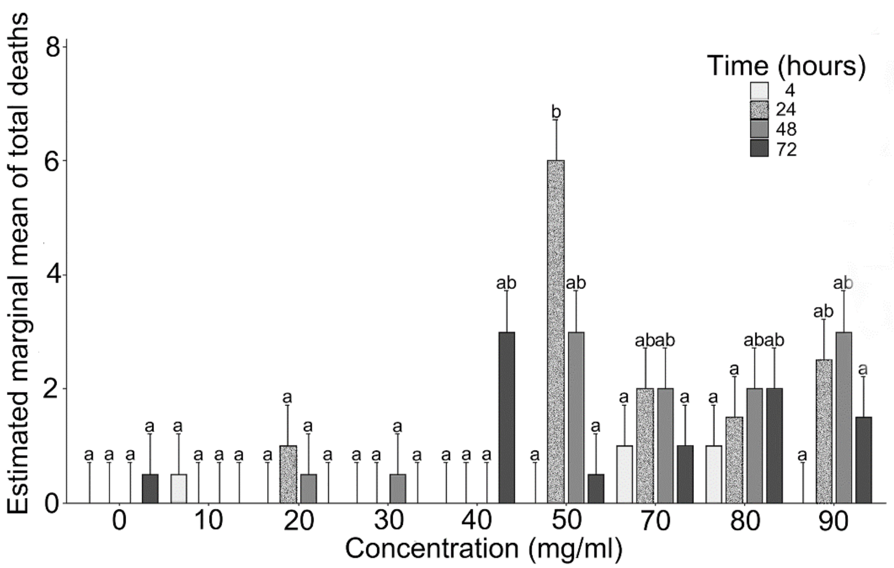

Fig. 6. Effect of concentration of *Cladonia foliacea* extract on mortality of male and female mosquitoes: Estimated marginal means after 4, 24,48, and 72 hours.(Concentrations by exposure time sharing similar letter are not significantly different regarding average total mortality.).

CONCLUSIONS AND RECOMMENDATIONS

The potential of lichen species and their secondary metabolites (LSMs) as insecticide agents has not been well explored, if the large number of lichen species (about 18,000-20,000) and that of LSMs (approximately 1,000 known) are considered and compared to the 32 species tested and 7 LSMs found to be effective. In the light of these numbers, the findings of this dissertation showing the insecticidal role of UA and its optical isomers and further confirming the effectiveness of *C. foliacea* extract containing UA and FA against *An. gambiae,* must be regarded important.

Kenya is one of the most studied countries regarding lichenological research in Africa, however, African lichens remain generally understudied indicating a potential for new distribution records, such as *Chrysothrix xanthina*, *Lobaria discolor*, *Parmotrema durumae* and *P. taitae* discovered as new from Tanzania; while *Usnea abissinica* and *U. sanguinea* are new in Kenya. Knowledge of host species of lichenicolous fungi is also limited. The revised identification key of lichens belonging to the parmelioid clade can promote conservation studies and the practical use of bioactive LSMs.

Populations of *F. caperata* from Europe (Hungary, Serbia) and Africa (Kenya, Tanzania) were confirmed to contain the (+)-UA enantiomer. Although high concentrations were found from samples collected in each region, no significant differences in usnic acid (UA) concentration were confirmed, future studies on the quantitative variations of UA using large sample sizes from wide and different geographical regions are recommended. However, *F. caperata* with (+)-UA enantiomer from these geographical regions can be further applied to explore its biological potential including insecticide role.

C. foliacea samples collected from Hungary, Albania, and North Macedonia have been confirmed to produce the (-)-UA enantiomer.

Therefore, this lichen can supply a source of bioactive substance, a potential raw material for further application.

This dissertation has provided promising evidence that lichen-derived secondary metabolites represent a novel approach to malaria vector control, especially targeting *An. gambiae*, a primary mosquito vector of malaria in Kenya. Pure (+)-usnic acid (UA) ingested in varying amounts has acute toxicity effects. Therefore, it can be recommended as a potential ingredient in the novel sugar bait method to control mosquitoes. Extracts from *C. foliacea*, which contain fumarprotocetraric acid (FA) and (-)-UA, also exhibit a killing effect when ingested in varying concentrations. The study highlights that integrating lichen-derived toxic sugar baits could contribute to innovative, sustainable insecticidal tools supporting integrated vector management. Consequently, both pure (+)-UA and extracts from *C. foliacea* thalli are recommended objects of further research for practical application to reduce malaria transmission in African countries.

NEW SCIENTIFIC RESULTS

1. An identification key to the 178 species of the parmelioid clade in Kenya, based on updated nomenclature, was produced to support the practical work in collecting and selecting certain parmelioid lichens for further research.
2. New distribution records were found in East Africa. The lichens *Bulbothrix kenyana*, *Chrysothrix xanthina*, *Lobaria discolor*, *Parmotrema durumae* and *P. taitae* were discovered as new for Tanzania; *Usnea abissinica* and *U. sanguinea,* furthermore lichenicolous fungi *Didymocyrtis* cf. *melanelixiae, Lichenoconium erodens* and *Spirographa lichenicola* are new for Kenya.

3. The presence and concentration of usnic acid enantiomers were established from earlier not studied geographical areas. The presence of lichen secondary metabolite (+)-usnic acid (UA) enantiomer was confirmed in samples of *Flavoparmelia caperata* originating from two continents: Europe and Africa. Substantial variation in the content of (+)-UA analysed by high-performance liquid chromatography (HPLC-PDA) was observed, but no significant differences between European (with 5.21 to 19.23 mg/g dry wt) and African (with 6.15 to 23.54 mg/g) samples were found. The presence of lichen secondary metabolites (-)-usnic acid (UA) enantiomer and fumarprotocetraric acid (FA) was confirmed in samples of *Cladonia foliacea* originating from Central and Southern Europe. The concentration ranges of UA (6.88 to 34.27 mg/g dry wt) and FA (1.44 to 9.87 mg/g dry wt) were established.
4. A protocol and further laboratory procedures for the novel attractive toxic sugar bait (ATSB) bioassay using adult mosquito candidates were worked out and approved by the scientific and ethics review unit of the KEMRI (SERU) protocol number SERU04–06–423/4610. It represents an important contribution to the World Health Organization Pesticide Evaluation Scheme (WHOPES).
5. For the first time it was revealed that oral administration of lichen secondary metabolite (+)-usnic acid, when combined with sugar solution, can kill male and female adult *Anopheles gambiae* primary malaria vector mosquitoes in Western Kenya. The efficacy was dose and time-dependent.
6. For the first time it was shown that acetone extract of the lichen *Cladonia foliacea* (containing (-)-usnic acid enantiomer and fumarprotocetraric acid applied as oral toxic sugar bait effectively killed both male and female *Anopheles gambiae.* Consequently, it is a promising biological oral toxic agent to be incorporated in the novel attractive toxic sugar bait for mosquito control to prevent malaria transmission.

LIST OF PUBLICATIONS SUPPORTING THE THESIS RESEARCH

Published papers in refereed journals

MUHORO, A.M. & FARKAS E.É. (2021): Insecticidal and antiprotozoal properties of lichen secondary metabolites on insect vectors and their transmitted protozoal diseases to humans. In: *Diversity* 13(8) 342.

FARKAS, E. & MUHORO A.M. (2022): Identification key to the lichen species of the parmelioid clade in Kenya. In: *Lichenologist* 54(5) 299–318.

FARKAS, E., LŐKÖS, L., MUHORO, A.M. & VARGA, N. (2023): New records of lichens and lichenicolous fungi from Kenya and Tanzania (East Africa). In: *Acta Biologica Plantarum Agriensis* 11 107–128.

FARKAS, E., KIRIKA P.M., SZABÓ K. & MUHORO A.M. (2024a): Concentration data of (+)-usnic acid enantiomer from some European and African samples of *Flavoparmelia caperata* (L.) Hale (Parmeliaceae, Lichenised Ascomycota) – results of a preliminary study. In: *Cryptogamie, Mycologie* 45(7) 71–82.

FARKAS, E., XU, M., MUHORO, A.M., SZABÓ, K., LENGYEL, A., HEIÐMARSSON, S., VIKTORSSON, E.Ö. & OLAFSDOTTIR, E.S. (2024b): The algal partnership is associated with quantitative variation of lichen specific metabolites in *Cladonia foliacea* from Central and Southern Europe. In: *Symbiosis* 92(3) 403–419.

MUHORO, A.M., KOSGEI, J.J, NJANGIRU, I.K., RASAKI, L.A. & FARKAS, E.É. (2024a): Potential of *Cladonia foliacea* extract as an oral toxic insecticide against adult *Anopheles gambiae*, malaria vector in Western Kenya. *Acta Botanica Hungarica* 66(3–4): 233–250.

MUHORO, A.M., OCHOMO, E.O., KINYUA, I.N., KOSGEI, J.J., RASAKI, L.A. & FARKAS, E. (2024b): A study on the effectiveness of (+)-usnic acid as oral toxic sugar bait against adult male and female *Anopheles gambiae*. In: *Malaria Journal* 23(1) 311.

Conference presentations related to the Thesis

MUHORO, A. & FARKAS, E. (2021): Másodlagos zuzmóanyagok hatása rovar-vektorokra és az általuk hordozott emberi kórokozókra – Irodalmi

áttekintés. In: TINYA, F. (szerk.) 12. Magyar Ökológus Kongresszus. Előadások és poszterek összefoglalói, MTA Ökológiai Kutatóközpont Ökológiai és Botanikai Intézet, Vácrátót, p. 155.

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MUHORO, A. & FARKAS, E. (2023a): Preparation and application of the identification key to the lichen species of the parmelioid clade in Kenya. In: HAJDÚ, P. (szerk.) XXVI. Tavaszi Szél Konferencia 2023. Absztrakt kötet, Doktoranduszok Országos Szövetsége (DOSZ), Budapest, p. 106.

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