The coneflower rosette mite (Eriophyoidea):

new insights into an established pest of *Echinacea* spp. (Asteraceae)

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Abstract

Although the common name "coneflower rosette mite" was coined c. 1994, little is known about the causal agent. We present preliminary data of eriophyoids sampled from *Echinacea* spp. floret galls from sites across the U.S., share results of an informal prevalence survey, and suggest diagnostic guidelines.

Keywords: Compositae, flower galls, phyllody

Intro

Echinacea is a genus of ~9 species of herbaceous perennials endemic to central North America, collectively called "coneflowers".[1]

Eriophyoids vector plant viruses, and are the only mites that induce galls. Although the exact mechanism of gall formation is unknown, studies indicate eriophyoid saliva has cytokinin-like and auxin-like properties.[2]

In August 2021, abnormal samples submitted to NCSU were diagnosed as induced by the coneflower rosette mite (**CRM**), and we began investigating:

1. What is known and unknown about this system?
2. Is this mite native or introduced?
3. How are CRM galls formed?
4. Is the CRM distinct from aster yellows?

Aster yellows (**AY**) is a bacterial disease induced by phytoplasmas. These bacteria are transmitted by homopteran insect vectors to phloem tissue and spread throughout the plant.[3] Some studies suggest eriophyoid mouthparts may be too small to pass phytoplasmas; however, the polymorphic nature of phytoplasmas indicates transmission cannot be ruled out.[4]

Here we share results of tests of CRM's for phytoplasmas, viruses, and genetic divergence, and compare CRM galls to similar symptoms caused by other agents. We also summarize responses to our survey of current knowledge and gaps in our understanding of this system, and suggest future study directions.

M&M

From Aug–Nov 2021 mites were collected from symptomatic *Echinacea* spp by the authors, and samples collected in 2013 and 2015 were contributed.[5] Total sites = 11, all gardens and nurseries; at two of those sites, mites were collected from live symptomatic plants purchased in California.

Galls and dormant subsoil buds were inspected, and mites removed, mounted on slides, and photographed. Morphological characters were compared to ~20 eriophyoids that either parasitize asteraceous plants or gall flowers.

Mitochondrial cytochrome c oxidase subunit 1 (COI) and ribosomal internal transcribed spacer (ITS) DNA regions were sequenced.[5]

Galled and ungalled tissue, as well as whole mites were analyzed via PCR and/or ELISA for phytoplasma, viruses, and viroids.[6]

Extension agents, *Echinacea* researchers and growers were asked if they'd encountered CRM symptoms, and a search for records was performed on websites including iNaturalist (LINK), Twitter, and the NPDN National Data Repository; full survey details presented separately.

Survey Results

Researchers at OSU Extension apparently invented the common name collectively after noticing instead of a disc floret, **CRM-infested florets develop into a leafy proliferation attached to a central "stalk", giving it a "rosette"-like appearance.**[7]

Although the name "coneflower rosette mites" is now commonly used, **the mite has yet to be taxonomically described**, and is currently unnamed on NDPN.

The CRM appears widespread; however, many respondents replied they may have seen it but were **unaware of, or unclear about, CRM symptoms, and/or assumed what they saw was AY.**

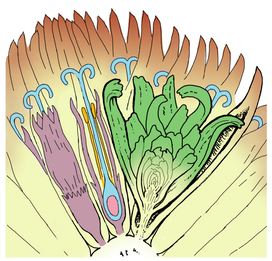
Numerous photos on public sites were found **misidentified as AY**, even by trained plant diagnosticians.

Morphological Results

Preliminary analyses suggest the CRM is an undescribed ***Aceria*** species, family **Eriophyidae**.

Galls are attached to the receptacle via a structure that resembles **shortened internodes.**

CRM's primarily affect **disc floret tissue - bracts and ray florets** often **less affected**



Molecular Results

1. All CRM's sampled have **identical COI & ITS** sequences.[5]

2. Whole mites[5], as well as galled & ungalled tissue[6] tested **negative for phytoplasma** (but positive for other bacteria[5]).

3. Galled & ungalled tissue tested **negative** for the following **viruses & viroids:**[6]

PCR (n=12): Begomovirus, Bromoviridae, Carlavirus, Carmovirus, Nepovirus, Pospiviroid, Potexvirus, Potyvirus, Tobamovirus, Tospovirus, Tomato ringspot virus, & Tymovirus

ELISA (n=13): Alfalfa mosaic virus, Arabis mosaic virus, Cucumber mosaic virus, Chrysanthemum virus B, Impatiens necrotic spot virus, Potyvirus, Ribgrass mosaic virus, Tomato aspermy virus, Tobacco ringspot virus, Tomato ringspot virus, Tobacco mosaic virus, Tobacco streak virus, & Tomato spotted wilt virus

DIAGNOSTIC GUIDE

CRM Symptoms

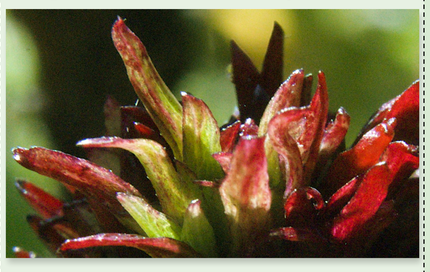
virescence **localized** to disc florets, **not ligules**

CRM ligules may be **stunted or absent**

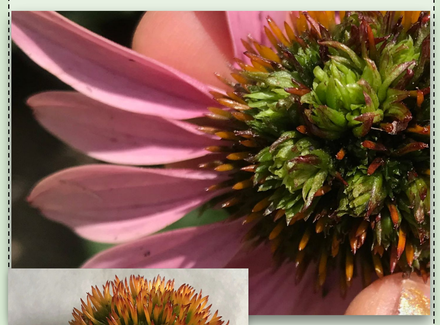
CRM galls **sessile or attached by a short "stem"**

subtending bracts may appear **enlarged, crooked, or shriveled**

tips of rosette "leaves" may turn red



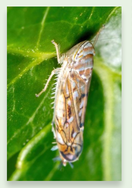
leafy, cabbage-like "rosettes" **without a hollow center**



fasciation *not* induced by, but found **co-occurring** with the CRM

Symptoms Similar to CRM

ligules green = aster yellows (AY)



a **phytoplasma** vectored by **leafhoppers**

AY florets may form an **elongated "stem"**

AY spreads **systemically** via phloem

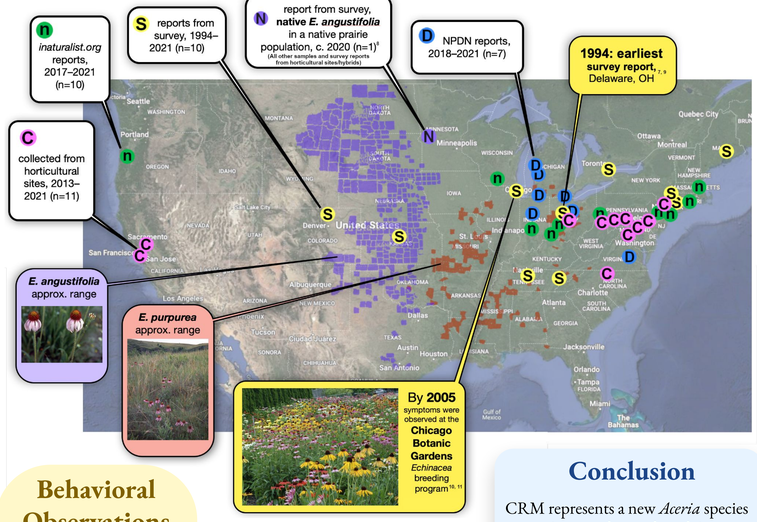
AY tips do *not* turn red

Unknown agents

Undissected galls on *E. pallida* in MO appear similar to galls caused by **midges**

florets develop thickened walls around a **larval chamber**

Unidentified gall agent on ***Rudbeckia laciniata***, a close relative of *Echinacea* spp.



Behavioral Observations

When infested florets begin to senesce, mites often **distally migrate** en masse, attach themselves by their caudal lobes, and extend their legs.

During plant dormancy, several **subsoil buds contained 1-2 deutogynes** (gravid females) each.

Discussion

Although symptoms of AY and CRM can appear nearly indistinguishable, our results show **they are indeed distinct causal agents.** In contrast to AY's **systemic** virescence, CRM symptoms are apparently **local only to areas where floral primordia contacts mite saliva.**

Eriophyoid CO1 and ITS regions are typically used to designate species-level divergence of eriophyoid mites.[12] Identical DNA regions found here imply **recent dispersal of a single species**, and **confirm expected divergence times found in samples obtained strictly from horticultural sites.**

These data are insufficient to resolve the questions: is the CRM **native to *Echinacea*, did it switch from another native asteraceous host (possibly asymptomatic on), or was it introduced via the horticultural trade?**

Studies suggest eriophyoids primarily disperse via wind; however, seasonal phoresy is reported.[13] **The mass migration observed here correlates with a period when *Echinacea* is visited by insects and seed-eating birds, and may allude to symbiotic transport.**

Standard treatment recommendations are interplanting and removal of symptomatic inflorescences as they appear. Our apparently unreported overwintering site indicates **soil-associated dispersal may be more common than previously thought.** It also raises the possibility that stubborn infestations might be mitigated by removing and sanitarily disposing new spring growth.

Conclusion

CRM represents a new *Aceria* species or species complex, and work is underway to taxonomically describe this mite. Our samples appear too-recently dispersed for the gene regions used to detect variation, and faster-evolving markers i.e. micro-satellites may detect divergence between these samples.[14]

DNA of native/wild-type samples are needed to resolve the origin. Although no phytoplasma nor viruses were detected, our tests did not rule out other viruses, fungi, other bacteria, and the causal mechanism remains unknown.

More studies are needed to investigate resistant cultivars, dispersal, as well as the process of gall induction.

References

1. Kindscher, K. (Ed.). (2016). *Echinacea: Herbal medicine with a wild history*. Springer, 238 pp.
2. de Lillo, E., Pozzebon, A., Valenzano, D., and Duso, C., (2018). An intimate relationship between eriophyoid mites and their host plants - a review. *Frontiers in Plant Science*, 9:1786.
3. Lee, I. M., Gundersen-Rindal, D. E., & Bertaccini, A. (1998). Phytoplasma: ecology and genomic diversity. *Phytopathology*, 88(12), 1359–1366.
4. Petanović, R. & Kielkiewicz, M. (2009). Plant-eriophyoid mite interactions: Specific and unspecific morphological alterations. Part II. *Experimental & Applied Acarology*, (51) 81–91.
5. Philipp Chetverikov, pers. comm.
6. Sladana Bec, pers. comm.
7. David Shetlar, pers. comm.
8. Stuart Wagenius, pers. comm.
9. Joe Boggs, pers. comm.
10. Jim Ault, pers. comm.
11. Richard G. Hawke, pers. comm.
12. Cruickshank, R. H., (2002). Molecular markers for the phylogenetics of mites and ticks. *Systematic and Applied Acarology*, 3–14.
13. Liu, S., Li, J., Guo, K., Qiao, H., Xu, R., Chen, J., Xu, C. & Chen, J. (2016). Seasonal phoresy as an overwintering strategy of a phytophagous mite. *Scientific Reports*, 6(1), 1–8.
14. Carew, M. E., Goodisman, M.A.D & Hoffmann., A.A. (2004). "Species status and population genetic structure of grapevine eriophyoid mites." *Entomologia Experimentalis et Applicata* 111.2:87–96.

Author contributions

Study design, sample collection, and analyses (except as below), as well as behavioral observations and text by MB and/or JS. MB proposed the study, JS coordinated it, conducted the survey and morphological analysis, and prepared a draft that MB revised. Both gave final approval for publication.

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Attribution and permits

From top left: photos of whole and cross-section plants by MB; gall illustration and CRM micrographs by JS. Image of CRM co-occurring with AY, Knoxville TN modified by JS from photo by Alan Windham, UT Extension; photo of sessile symptoms MB, other CRM symptoms, JS; leafhopper and midge MB; old AY by Suzanne McTiver, granted by NDSU Extension c/o Donald Kinzler; AY systemic spread by Penn State Department of Plant Pathology & Environmental Microbiology Archives c/o Bugwood.org, licensed under a Creative Commons Attribution-Noncommercial 3.0 License; unknown gall agent by inaturalist.org user *mwilvis*, licensed under Creative Commons: Attribution-NonCommercial 4.0 International License; midge (*Asphondylia ratibidae*) galls on *Ratibida pinnata* and chamber close-up by John Pearson, Botanist/Ecologist with Iowa Department of Natural Resources, licensed under Creative Commons: Attribution-NoDerivs-NonCommercial 1.0 Generic (CC BY-ND-NC 1.0) License; unknown gall on *Rudbeckia laciniata* by Chris Evans, University of Illinois, c/o Bugwood.org, licensed under a Creative Commons Attribution-Noncommercial 3.0 License. Caudally attached mites by MB; *E. angustifolea* by Clarence A. Rechenthin c/o USDA-NRCS PLANTS Database; *E. purpurea* habitat by Jack Dykinga, USDA Agricultural Research Service; CBG breeding plot by Jim Ault, emeritus, granted by Richard G. Hawke, Plant Evaluation Manager and Associate Scientist at CBG; base map modified by JS from map data (c) 2022 Google, INEGI, licensed for public display; species range layer modified by JS from maps presented in ref. #1, from data provided by Jennifer Delisle, Kansas Biological Survey; subsoil bud by JS.

Conflict of interest

MB is a member of the NPDN. Cultivars tested include "Sombrero® Adobe Orange", registered trademark of BHC, as well as variety "Cheyenne Spirit", developed by PanAmerican/Kieft Seeds, now owned by BHC. Plants were purchased wholesale, as licensed by Berkeley Garden Care (BGC); JS was sole proprietor of BGC (now closed).

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