Cryptococcus fagisuga Lindinger, 1936 (Hemiptera, Cryptococcidae) confirmed from Norway

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We here confirm the presence of *Cryptococcus fagisuga* Lindinger, 1936 (Hemiptera, Coccomorpha, Cryptococcidae) from Norway with two new records, one of them probably representing the northernmost find of this species worldwide. We discuss its history in Norway.

Key words: Hemiptera, Coccomorpha, Cryptococcidae, *Cryptococcus fagisuga*, Norway.

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Introduction

The knowledge of the scale insects (Hemiptera, Coccomorpha) in Norway is very poor compared to our neighbouring countries. The latest checklist was compiled by Fjelddalen (1996), who lists and comments on the biology and distribution of 36 species of scales found in Norway (including greenhouse species).

The scale family Cryptococcidae consist of two genera; *Cryptococcus* Douglas, 1890 and *Pseudochermes* Nitsche, 1895. There are only eight species in this family worldwide (García Morales *et al.* 2016). *Pseudochermes fraxini* (Kaltenbach, 1860) was first reported from Norway by Schøyen (1930). This is the only record of this species in Norway, and *P. fraxini* is the only other representative of the family Cryptococcidae reported from Norway. Regarding *Cryptococcus fagisuga* Lindinger, 1936 in Norway, the status has been somewhat unclear.

Cryptococcus fagisuga (syn. *Cryptococcus fagi* (Baerensprung, 1849)) was never listed by Fjelddalen (1996) even though the species probably already was present in the Norwegian fauna at the time. It is neither listed from Norway in García Morales *et al.* (2016), Burckhardt (2017) or CABI (2021). We here present new records for this species and discuss its history in Norway.

Material and methods

An observation of a *Fagus sylvatica* full of white «wool», possibly Pseudococcidae, was reported to the Norwegian Institute for Nature Research (NINA) from Ålesund municipality in May 2018. The species was identified based on photo as cf. *Cryptococcus fagisuga* (Cryptococcidae) by the first author, later confirmed after specimen examination by the second author.

In 2020 the first author investigated parts of a beech forest in Larvik municipality and retrieved two samples of coccids that were sent to the second author and confirmed to be *C. fagisuga.* The specimens were slide mounted using the

method described by Danielsson (1985) and Kosztarab & Kozár (1988). The insects were dewaxed for three days in a solution of 40% xylene, 40% ethyl acetate and 20% ethanol (96%). The specimens were then heated gently in 96% ethanol, 10% KOH and 50% lactic acid respectively. The cleared insects were placed in Essig's Aphid Fluid with staining solution according to the method of Kosztarab and Kozár (1988). After clearing in clove oil, they were mounted in Euparal.

The key used for identification is found in Kosztarab & Kozár (1988). The Norwegian regions follows Endrestøl (2021), and EIS-system follows (Endrestøl 2005).

The records

VE, Larvik: Bøkeskogen (EIS 19, XIII.2018), on *Fagus silvatica*, photo: M. Petterson, det. Talgø *et al.* 2019; Larvik: Bøkeskogen (EIS 19, N59.05696 E10.02639 and N59.05648 E10.02375, 14.VIII.2020), leg. A. Endrestøl, det./coll. C-A. Gertsson. **MRY**, Ålesund: Grensegata 1 (EIS 76, N62.47184 E6.167413, 14.V.2018 (photo), 4.VI.2018 (specimens/photo)), on *Fagus sylvatica*, leg./photo. L. Fiskerstrand Sperre (Ålesund municipality) and D. Armitage (Sandal parkdrift), det./coll. C-A. Gertsson.

The locality in MRY is a small park situated in the intersection of three roads, Borgundvegen, Keiser Wilhelms gate and the pedestrian walkway in the extension of Grensegata in Ålesund. The park houses two large trees, one *Fagus sylvatica* and one *Fagus sylvatica* f. *purpurea/ atropunicea*. In addition, there was one *Prunus* 'Accolade' (planted there around 2016), one *Sambucus racemosa* and some individuals of *Spirea* (L. Fiskerstrand Sperre pers. com.). A large part of the *F. sylvatica* tree was covered with *C. fagisuga*, and was apparently the only tree infected in the area (Figure 1).

Cryptococcus fagisuga was in august 2018 photo-documented in Bøkeskogen, Larvik municipality (Talgø *et al.* 2019). Additional specimens from Bøkeskogen, Larvik municipality was collected by the first author in august 2020 and later determined by the second author (Figure 2). Bøkeskogen (The Beech Tree Forest) bordering Larvik city is the largest (0.3 km^2 - 74 acres) in Norway and one of the world's most northerly beech tree forest (Telfer *et al.* 2015).

FIGURE 1. *Cryptococcus fagisuga* on *Fagus silvatica* from Ålesund municipality 4. June 2018. Photo: Linda Fiskerstrand Sperre (Ålesund kommune).

Biology, distribution and host-plants

Diagnostics and information on the life cycle of *C. fagisuga* can be found in Miller & Miller (1993). *C. fagisuga* is a parthenogenetic, oviparous species, and males are unknown (Miller & Miller 1993). According to Miller & Miller (1993) the life cycle can be summarized as follows: «eggs are laid in the spring within ovisac. The eggs hatch in late summer and fall, and mobile crawlers are settling in cracks or lenticle depressions on the bark. Soon after establishment, a filamentous secretion is produced that completely surrounds the crawler. The first instar is normally the overwintering stage, but in some areas both eggs and crawlers

FIGURE 2. *Cryptococcus fagisuga* on *Fagus silvatica* from Larvik municipality 14. August 2020. Photo: Anders Endrestøl (NINA).

may be present in the winter. During the spring, molting occurs and the apodous second instar is produced. This instar is apparently short lived. Adult females occur throughout the spring and summer». According to Japoshvili *et al.* (2015), phenology on nearly identical growing seasons can vary, with individuals being bivoltine in the Caucasus Mountain region (Georgia), with overwintering adults, but univoltine in Massachusetts (USA) with the overwintering stage being 1st instars.

Cryptococcus fagisuga is associated with four host plants; *Fagus grandifolia, F. orientalis, F. sylvatica* (including f. *atropunicea* and f. *laciniata*) and *Pinus sylvestris* (Gertsson 1997, García Morales *et al.* 2016), up to 1200 m.a.s.l. (Kosztarab & Kozár 1988). The record from *Pinus sylvestris* is from one locality (Kosztarab and Kozár 1988), but the identity of this sample is uncertain (CABI 2021). According to García Morales *et al.* (2016), *C. fagisuga* is found in 29 countries worldwide (30, including Norway). Its widely distributed in Europe, and first mentioned from Denmark in 1923 by Boas (1923) cited in Kozarzhevskaya & Reitzel (1975). *Cryptococcus fagisuga* is mentioned as one of the most damaging coccid species in Denmark by Kozarzhevskaya (1986). In Sweden it is widely distributed in Skåne and Blekinge, and in Skåne an investigation of the beech-forests found *C. fagisuga* on 46 out of 48 investigated forests (Jönsson 1998). Jönsson (1998) found that algae cover and *C. fagisuga* were positively correlated, and that both preferred sites with no direct light exposure, high nitrogen deposition and low pH. *Cryptococcus fagisuga* is also found in the USA and Canada, Russia and eastward to Iran. It is regarded as invasive in the Nearctic, first discovered there in 1911 in Halifax, Canada (Hewitt 1914). Its native range is suspected to be in Bulgaria, the Caucasus Mountain Region (Georgia), Turkey, or Iran (Driesche and Japoshvili 2013). The subspecies *F. sylvatica orientalis* is probably the native host of *C. fagisuga* (Gwiazdowski *et al.* 2006).

Cryptococcus fagisuga is also associated with Beech Bark Disease (BBD), and in some cases the sole and necessary predisposing factor to fungal infection (*Neonectria* spp.) (Cale *et al.* 2017). With both agents present the disease build up in three phases: 1) Advance front; where scale populations slowly and steadily increase for up to ten years before exhibiting rapid growth, reaching densities as high as 270 scales/cm^2 of bark, 2) Killing front; Beech scale infestations are heavy, abundant *Neonectia* spp. infections on beech stems coalesce, girdle the vascular cambium, and kill the crown and stem above the girdle, 3) Aftermath; following the heavy mortality of the killing front, forests transition to the aftermath stage characterized by reduced levels of beech scale, *Neonectria* spp., and aboveground beech mortality as well as increased understory beech prevalence (see review and references in Cale *et al.* 2017). Symptoms of BBD includes felted, white wax filaments in cracks in the bark and under bark flakes, bark cracking, bark exudates, discoloration of the sapwood, and as infections mature, the red fruiting bodies of the *Neonectria* fungus emerging from the bark (Driesche and Japoshvili 2013, CABI 2021). According to Cale

et al. (2017), BBD is among the most important forest diseases in eastern North America in terms of temporal and spatial extent as well as negative impact.

Discussion

The story of *Cryptococcus fagisuga* in Norway is a bit complex and vague, and it is to this date not been regarded as a Norwegian species (Fjelddalen 1996, Artsnavnebasen 2020). The species is though mentioned in Löyttyniemi *et al.* (1979) as follows «*Of the scale insects,* Cryptococcus fagi *Bär. was found in large numbers on* Fagus silvatica *in southern Sweden and southern Norway […]*». Later, it was also reported by Austarå *et al.* (1984) as follows: «*In 1977* C. fagi *was also discovered in a beech stand in a southern locality in Norway*». It is not at all clear if these references concern the same locality, but as Löyttyniemi *et al.* (1979) covered the period 1972–76 and Austarå *et al.* (1984) covered the period 1977–1981, it would be reasonable to think that it might be a new discovery of a second locality. No further information is given on the species/specimen, date or localities in these reports.

According to K. Fresjarå (forest manager in Larvik 1971–2012), he discovered this species in the beech forest in Larvik municipality in 1974, in an area previously planted with beech («Festplassen») (K. Fresjarå pers. com.). Later, different aspects of forest damage, including *C. fagisuga*, were evaluated in this forest by K. Venn and Ø. Austarå (K. Venn pers. com.). K. Fresjarå visited in 1987 Denmark, where he got first-hand information and further field experience with *C. fagisuga* from prof. Broder Bejer-Petersen at the University of Copenhagen (K. Fresjarå pers. com.). It therefore no reason to doubt that *C. fagisuga* was present in the beech forest in Larvik municipality at the time.

It has though not been possible to confirm whether Ø. Austarå identified *C. fagisuga* in the field or if he collected specimen for later identification, and if any specimen is preserved. The institute where Austarå was affiliated (Det norske skogforsøksvesen, now Norwegian Institute of Bioeconomy Research, NIBIO) does not have any Norwegian specimen of *C. fagisuga* in their collection, but they have two foreign exsiccate specimen from 1908 and 1919 (N. Svae Johansen pers. com), probably available as reference specimen for Ø. Austarå at the time. To our knowledge this species has never been properly documented from Norway before, even though it has been anecdotally referred to in media and grey literature. It has probably also been confused with *Phyllaphis fagi* (Aphididae) in some instances.

Forest managers of the beech forest in Larvik have taken measures against *C. fagisuga* since the discovery, and have been cutting down and burning several trees, e.g. based on practises given in Bogenschutz and König (1982). Our impression is that these measures have been based on apparent symptoms on the beeches, like withering leaves in the crown, rather than actually seeing the scale. Practises concerning *C. fagisuga* have been given lesser priority in the newest management plan for this forest (Fylkesmannen i Vestfold 2013). According to Bejer-Petersen (1966), *C. fagisuga* should be regarded as a secondary pest, having mass occurrences mainly on already weakened beech trees. It is also reason to believe that the infestation rates of *C. fagisuga* on beech depend on tree age and canopy openness rather than on management intensity (Köhler *et al.* 2015).

Fagus sylvatica is at the northernmost known presumed native localities in Norway of this species in Europe (Bjune *et al.* 2012). How beech became established and spread in Norway is disputed, but some of the known beech forests have a long history in Norway (> 1000 cal. B.P.) based on pollen analysis (Bjune *et al.* 2012). The world's northernmost beech forest is situated at Lygresfjorden close to Bergen (Holmboe 1909) where the species probably was introduced from Vestfold during the Viking period (Fægri 1954). The tree species also have a long history of being planted in parks for ornamental purposes, and it is p.t. widely distributed along the Norwegian coast north to Trøndelag county, with a single individual registered from Ibestad municipality in Troms and Finnmark county (Artskart 2020). All beech individuals north of – and 200 km south of the

locality for *C. fagisuga* in MRY are thus planted and of relatively young age. We suspect that the record of *C. fagisuga* at lat. 62.47° N given here is the most northern record of this species worldwide.

One could speculate in how *C. fagisuga* has become established so far north, or in Norway in general. Crawlers may be transported on body surfaces of birds and other insects (Kosztarab & Kozár 1988). Also, first instars of *C. fagisuga* are dispersed passively on air currents (Wainhouse 1980), so a long distance dispersal with jet-streams could be a possible explanation. Another reasonable hypothesis would be that the species have been spread as a hitchhiker on imported beech. There are several examples of hemipterans that have been established in Norway the recent years, suspected to be vectored by plant import (e.g. Ødegaard & Endrestøl 2007, Endrestøl et al. 2016, Endrestøl 2008, 2017). This argument is supported by the fact that *C. fagisuga* first was discovered on planted beech in Larvik (K. Fresjaå pers. com.). The plant import to Norway has increased a lot the last decades, including the import of beech (Westergaard *et al.* 2018).

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