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A report on occurrence, morphology, population ecology and infestation of *Ceroplastes rusci* (Linnaeus: 1758) in Muzaffarnagar, Uttar Pradesh, India. Coccidae: Coccoidea: Hemiptera: Insecta

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Abstract
The presence of *Ceroplastes rusci*, the Fig wax scale infestation was observed on *Syzygium cumini,* the Indian blackberry or Jamun tree twigs and leaves in Muzaffarnagar, Uttar Pradesh, India. The number of adult female scale insects, per leaf, was found 1 to 6, and per twig the number was observed as 1 to 9. The present study was carried out to assess the presence of scale insects per leaf and a single terminal twig. After analysis of collected data, the following results were calculated for the presence of scale insect on a leaf- as the mean value was calculated- 2.1666, SD- 1.6966, variance- 2.8787 and margin of error- 0.4897. Data were analyzed similarly for presence of scales per twig. The calculated values for twig were as- mean-3.83, SD-2.48, variance- 6.15 and margin of error- 0.7159. The percent infestation on *Syzygium cumini* plant on twig/ leaf was calculated and found that 52.30% plant twigs were affected. The categorized infested twigs with leaves showed 13.84% of grade one as low (+), 16.62% of grade two as moderate (++) and 21.53% of grade three as high (+++) level of infestation. The 47.69% twigs were found showing absence (-) of scale insects. *Syzygium cumini* was the type plant, found affected in Muzaffarnagar, the region of planes of northern India, indicating the ecological relationship and interaction between scale insect and affected plants. New generation was observed in first half of July 2023. No other type of surveyed plant was found infested.

Keywords: Coccidae, Hemiptera, *Syzygium cumini*, *Ceroplastes rusci*, antimutagenic, phenolics, anthocyanins

Introduction
The presence of *Ceroplastes rusci*, the Fig wax scale infestation was observed on *Syzygium cumini*, the Indian blackberry or Jamun tree twigs and leaves in Muzaffarnagar, Uttar Pradesh, India. Muzaffarnagar district is located in the northern part of Indian region and falls in western Uttar Pradesh, Saharanpur division and in Doab region of Indo-Gangetic plains. The Muzaffarnagar is situated at Longitude 77.6 and Latitude 29.4. The sub-tropical climate prevails over this district. Jamun, the Indian blackberry, is a big size perennial tree and being planted in gardens, on road sides or in parks etc. This is also an important tree being used for its economic importance as fruits, seeds and timber. The fruits and seeds are clinically significant, for nutraceutical values and are used in the treatment of diabetes mellitus and other disorders. The fruits extracts showed anti-inflammatory, antioxidant, anti-diabetic, anti-mutagenic activity and also as detoxifier and protection from radioactivity. The main ingredients of fruit pulp of blackberry are anthocyanins and phenolic compounds. The extracts of blackberry fruits exhibited a potent action against cancer and various tumour progression cell lines in different test systems. In the summer months, May and June of year 2023, the presence and infestation of *Ceroplastes rusci* came in notice in Muzaffarnagar, India. The infested tree was of an age of four years and the size of 15 feet approximately. This is small sized, tiny round umbrella/bell shaped, the female fig wax scale, the *C. rusci* is a less active insect, attached to foliage and twigs of plants. During the investigating observations, the good number of scales were noticed on infested plants. The fig wax scale, *Ceroplastes rusci* (Linnaeus 1758): Coccidae: Hemiptera, infestation was first observed in Florida at several

nurseries and stock dealers in 1994 and 1995. It has been a pest of *Ixora Spp*. and infrequently found on other host plants. The California department of Food and Agriculture has intercepted specimens from Florida, prior to discovery in Florida. The presence of this scale in the Mediterranean region as in Algeria, Cyprus, Egypt, Greece, Israel, Italy, Lebanon, Morocco, Spain, Tunisia, Turkey and Argentina was reported by Talhouk (1975) [27].

The presence of fig wax scale, *C. rusci* was reported from various of African and Asian countries. These scale insects were also found in Australia (the Northern territory), Papua, Central America and Caribbean as in Antigua, Dominion Republic, Puerto Rice Virgin Islands, Europe- Albania, Balearic Islands, Corsica, Crete, Cyprus, France, Gibraltar, Greece, Italy, Malta, Portugal, Sardinia, Sicily, Spain, Turkey, and Yugoslavia and also reported in Argentina, Brazil, Guyana, and in Uruguay. (Ben-Dov-1993, CABI, 2011, Vu *et al*. 2006) [4, 28]. In North America, it appears that it is only established in Florida (U.S.) (Hodges *et al*. 2005) [12]. This scale is deeply encased in pinkish-grey wax, which is divided into three wax plates on each side with additional plates at the anterior and posterior ends. The single large dorsal plate has a central nucleus. Dorsal and lateral plates are separated from each other by dark red lines which are the colour of the scale's body beneath the wax. The antero-lateral and medio-lateral plates have some white wax which indicates the stigmatic wax bands.

Ceroplastes rusci is considered a serious pest of fruit trees in many countries. Fig wax scale feeds by inserting its stylet in to host leaves, shoots and fruits. Heavy infestations of the scale cause yellowing, loss of foliage, and poor fruiting and fruit set (Vu, Nga Thi, *et al*. 2006) [28]. The scale has a polyphagous nature of feeding and, feeds on different varieties of plants in at least 48 families (Culliney, T.W. 2014) [9]. Almonds, grape, citrus, pistachio, avocado, cotton, fig, palms, pear, the most economically important plants and a variety of ornamental plants are the host plants of *C. rusci*. *C. rusci* can move and migrate long distances through the shipment of infested palm trees as well as other host plants and plant parts. These scale insects are responsible for significant damage in plant parts and a loss in crop yield.

Ceroplastes rusci is supposed to be native to tropical Africa. About 100 per cent of plant infestation by *C. rusci* in *Annona muricata* was recorded with 100 per cent of its shoot infestation (Vu *et al*. 2006) [28]. *Ceroplastes rusci* infestation in fig was recorded with about 500 nymphs per twig (Bodkin 1927; Balachowsky & Mesnil 1935; Khasawinah & Talhouk 1964; Talhouk 1969; Argyriou & Santorini 1980; Mustafa-Al-Antary & Al-Momany 1990; Mustafa-Al-Antary & Sharaf 1994) [7, 2, 26, 1, 15, 23, 24]. In India *C. rusci* has been reported infesting *Mangifera indica*, *Dalbergia sissoo*, *Syzygium* sp., *Ziziphus mauritiana*, *Citrus* sp., *Ficus benghalensis*, *F. religiosa*, *F. rubiginosa*, *F. microcarpa*, *F. retusa* and *F. carica* (Del Guercio 1906; Balachowsky & Mesnil 1935; Talhouk 1975; Morsi & Mousa 2003; Vu *et al*. 2006; Mifsud *et al*. 2012; Kumar 2013) [10, 2, 27, 28, 19, 16]. *Ceroplastes rusci* was also reported as a significant vector of plant viruses (La Notte *et al*. 1997) [18]. Ben-Dov (1993) [4] reported 39 plant species hosting *C. rusci* and subsequently, Morales *et al*. (2016) [20] listed 137 host plant species belonging to 48 families of the world. The finding of the workers proves that *C. rusci* has wide range of host plants worldwide. Kumar, A. (2013) [16] conducted a survey study in Jharkhand, India. His investigation revealed *that Dalbergia sissoo* was found highly susceptible for infestation of *C. rusci* affecting plant with 24.16 percent. It was reported that insect population as 23.33 insects were present per twig and 10 insects per leaf. New host plants were also recorded in a study carried out in Uttrakhand, India (Kumar, A and Pandey, R. 2022) [17]. Pellizzari, G. *et al*. (2010) [24] described the morphology and phenology of immature female instars of *Ceroplastes rusci*. Shan, Y. *et al*. 2022 [25] predicted the potential distribution areas of *C. rusci* using Maximum Entropy (MaxEnt) based on the occurrence data and environmental variables under current and future climatic scenarios. They warned about the infestation of *C. rusci* in other suitable regions under climatic change, which are still unaffected.

Material and Methods

During the investigation time period, the survey based occurrence, population ecology, and level of damage to plants were considered for study. The *C. rusci* was identified by taking the digital photos and by comparing the morphological characteristic features as per the referred reports of Gimpel *et al*. (1974) [11], Williams and Watson (1990) [29-30] and Hodgson and Peronti (2012) [14]. The morphological micrographs were taken in 10X5X magnification by compound microscope. The possible environmental factors, which inducted the distribution and infestation of this scale insect, were also studied, related to favourable type of plants in the region of study. On plants, the counting of scales was done on leaves and twigs. The population presence were analysed to assess the number of scales per leaf and twig. The population/infestation data were analysed statistically to calculate the statistical results. The percent infestation was also calculated.

Results and Discussion

In the months of May and June 2023, when the general atmospheric temperature goes higher, touching the 42^0C or more than this level, the presence of *Ceroplastes rusci* was noticed on *Syzygium cumini*, the Indian blackberry (Jamun) tree leaves and twigs. This is a tiny umbrella shaped, a size of approx.3.5 mm. in diameter, with a circumference of 10.99 mm. approx, a central apical nucleus, called as Fig wax scale, female, exhibiting somewhat whitish or cream colour of body. The size was found varied based on development, as smaller in early developmental stage. The colour turns to light brown when this scale insect attains growth in size. The scales are attached to upper and lower surfaces of leaves, on midrib of leaf, and twigs. During the study survey, the different types of garden fruit trees and other types of trees were observed to record the presence of this scale insect. In the list, the types of observed plants were as Jamun or Indian black berry (*Syzygium cumini*), Sheesham (*Dalbergia sissoo)*, Mulberry (*Morus alba*), Mango (*Mangifera indica*), Sagaun teak (*Tectona grandis*), Lemon (*Citrus limon*), Bhel (*Aegle marmelos*), Guava (*Psidium guajava)*, Litchi (*Litchi chinensis*), Chicco or Sapodilla (*Manilkara zapota*), Peach (*Prunus persica*) plants. It was observed that the scale insects were present on Jamun trees only, which was found the only preferred plant for shelter, food and feeding. The twigs were equally preferred for attachment as leaves. At some places, the twigs were preferred over leaves as showed higher density. The number of adult female scale insects, per leaf, was found 1 to 6, and on per terminal twig the number was observed as 1 to 9. When the dome shaped structure, made up of *C. rusci* was detached from surface and averted, then

hundreds of light brown coloured, with wax at posterior end, tiny scales, crawlers (nymphs) came out and showed active movement. The tiny nymphal instars of scales had wax at posterior end. The *C. rusci* dome shape plated structure serves as a shelter for tiny initial instars of insects. The severe infestation was recorded on approximately four years age tree of Indian black berry plant, (Jamun) the *Syzygium cumini*. Scale insects have high reproductive and fecundity potential under favourable environmental and feeding conditions. These scale insects were responsible for a significant damage in plant parts as leaves and similarly for a loss in crop yield as blackberry fruits. The adult females overwinter on twigs and produce eggs very early in the spring. The eggs hatch to crawlers which move to feed on leaves. After about one month, the crawlers moult to second instar nymphs and migrate to the leaf petioles or to new shoots. Scales get maturity in summer, and a new generation of crawlers is produced. These nymphs mature late in the fall, overwinters on twigs, and repeat the cycle (Bodkin, 1927) [7]. Ben-Dov, Y. (1970) [5] studied the wax scale of *Ceroplastes* Gray (Homoptera: Coccidae) and their parasites in Israel. The scale insects of Israel- checklist, host plant, zoogeographical considerations and annotations on species were assessed (Ben-Dov, Y. 2012) [6]. *Ceroplastes rusci* was recorded to be infesting to *D. sissoo* tree with an intensity of about 23.33 insects per twig and up to 10.00 insect per leaf (Kumar 2013) [16]. The study report also revealed that plants of Moraceae family were preferred hosts of *C. rusci* in the study area. Six new host plant species of *C. rusci* recorded from India, indicated that *C. rusci* is a polyphagous species and there are additional host plants yet to be detected (Kumar 2013) [16]. A review article published by Beauti K. *et al.* (2023) [3] on the scale insects describing status, biology, ecology and management in tea plantations. The scale insects cause significant damage to tea crop by sucking sap from leaves of tea and promote the growth of sooty molds affecting nutritional quality of tea leaves. In this review article the strategies for control and management of this serious sucking tea insect pest were discussed.

The present study was also carried out to assess the presence of scale insects per leaf and a single terminal twig. After analysis of collected data, the following results were calculated- as the mean value was calculated- 2.1666, SD- 1.6966, variance- 2.8787 and margin of error- 0.4897. Data were analyzed similarly for presence of scales on per twig. The calculated values for twig were as- mean-3.83, SD-2.48, variance- 6.15 and margin of error- 0.7159. The atmospheric temperature was also recorded during investigation study period. The minimum atmospheric temperature ranged between 5.4^0C to 29.1^0C and maximum atmospheric temperature ranged between 20.1^0C to 41^0C from Feb. 2023 to June 2023 with fluctuating humidity as per the conditions of atmospheric temperature in study region.

Number of scale insect on a single leaf-

Standard Deviation, s: 1.6966991126266
Count, N: 12
Sum, Σx: 26
Mean, x̄: 2.1666666666667
Variance, s2: 2.8787878787879

Steps

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

$$s^2 = \frac{\Sigma(x_i - \bar{x})^2}{N - 1}$$

$$= \frac{(1 - 2.1666666666667)^2 + \ldots + (1 - 2.1666666666667)^2}{12 - 1}$$

$$= \frac{31.666666666667}{11}$$

$$= 2.8787878787879$$

$$s = \sqrt{2.8787878787879}$$

$$= 1.6966991126266$$

Margin of Error (Confidence Interval)

$$s_{\bar{x}} = \frac{s}{\sqrt{N}} = 0.48979484470438$$

Based on the SEM, the following are the margins of error (or confidence intervals) at different confidence levels. Depending on the field of study, a confidence level of 95% (or statistical significance of 5%) is typically used for data representation.

Confidence Level	Margin of Error	Error Bar
68.3%, $s_{\bar{x}}$	2.1667 ±0.49 (±22.61%)	
90%, 1.645$s_{\bar{x}}$	2.1667 ±0.806 (±37.19%)	
95%, 1.960$s_{\bar{x}}$	2.1667 ±0.96 (±44.31%)	
99%, 2.576$s_{\bar{x}}$	2.1667 ±1.262 (±58.23%)	
99.9%, 3.291$s_{\bar{x}}$	2.1667 ±1.612 (±74.40%)	
99.99%, 3.891$s_{\bar{x}}$	2.1667 ±1.906 (±87.96%)	
99.999%, 4.417$s_{\bar{x}}$	2.1667 ±2.163 (±99.85%)	
99.9999%, 4.892$s_{\bar{x}}$	2.1667 ±2.396 (±110.59%)	

Frequency Table

Value	Frequency
1	6 (50%)
2	3 (25%)
3	1 (8.333%)
5	1 (8.333%)
6	1 (8.333%)

Counting analysis on a single terminal Twig-
Standard Deviation, s: 2.4802248187443
Count, N: 12
Sum, Σx: 46
Mean, x̄: 3.8333333333333
Variance, s2: 6.1515151515152

Steps

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

$$s^2 = \frac{\Sigma(x_i - \bar{x})^2}{N - 1}$$

$$= \frac{(3 - 3.8333333333333)^2 + \ldots + (5 - 3.8333333333333)^2}{12 - 1}$$

$$= \frac{67.666666666667}{11}$$

$$= 6.1515151515152$$

$$s = \sqrt{6.1515151515152}$$

$$= 2.4802248187443$$

Margin of Error (Confidence Interval)
The sampling mean most likely follows a normal distribution. In this case, the standard error of the mean (SEM) can be calculated using the following equation:

$$s_{\bar{x}} = \frac{s}{\sqrt{N}} = 0.7159792333764$$

Confidence Level	Margin of Error	Error Bar
68.3%, $s_{\bar{x}}$	3.8333 ±0.716 (±18.68%)	
90%, 1.645$s_{\bar{x}}$	3.8333 ±1.178 (±30.72%)	
95%, 1.960$s_{\bar{x}}$	3.8333 ±1.403 (±36.61%)	
99%, 2.576$s_{\bar{x}}$	3.8333 ±1.844 (±48.11%)	
99.9%, 3.291$s_{\bar{x}}$	3.8333 ±2.356 (±61.47%)	
99.99%, 3.891$s_{\bar{x}}$	3.8333 ±2.786 (±72.68%)	
99.999%, 4.417$s_{\bar{x}}$	3.8333 ±3.162 (±82.50%)	
99.9999%, 4.892$s_{\bar{x}}$	3.8333 ±3.503 (±91.37%)	

Frequency Table

Value	Frequency
1	3 (25%)
2	1 (8.333%)
3	2 (16.666%)
4	1 (8.333%)
5	2 (16.666%)
6	2 (16.666%)
9	1 (8.333%)

The presence of this scale showed an increased value of mean-3.75, SD-1.36 and variance-1.85 for leaf infestation and mean-12.5, SD-3.09 and variance-9.58 for twig infestation in the month of July of 2023. The per cent infestation on *Syzygium cumini* plant on twig/ leaf was calculated and found that 52.30% of plant twigs were affected. The categorized infested twigs with leaves showed 13.84% of grade one as low (+), 16.62% of grade two as moderate (++) and 21.53% of grade three as high (+++) level of infestation. (Fig.1).

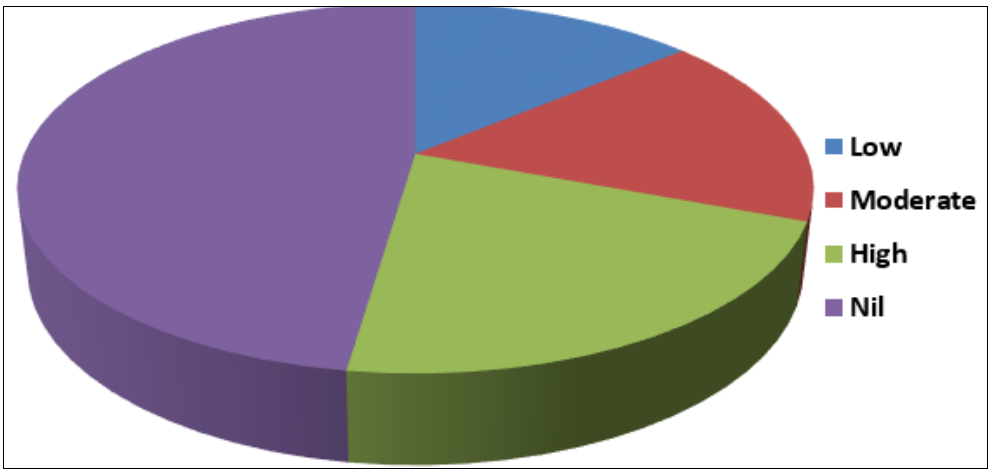

Fig 1: Showing grade and percentage of infestation caused by *C. rusci*

Fig 2: Image of *Ceroplastes rusci* on the leaf of *Syzygium cumini*

The 47.69% of twigs were found to show absence (-) of scale insects. *Syzygium cumini* was the type plant, found affected in Muzaffarnagar, the region of planes of northern India, indicating the ecological relationship and preferable interaction between scale insect and Indian blackberry plant. No other type of surveyed plant was found infested. The next generation was observed in first half of July 2023, with an increased number of female individuals on twigs of the blackberry plant.

Fig 3: *Ceroplastes rusci* on a twig.

Fig 4: *Ceroplastes rusci* on leaf midrib showing different developmental stages.

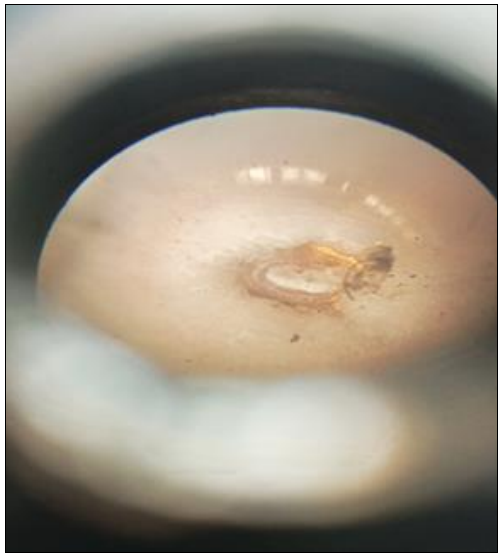

Fig 5: The micrograph (10X5X)

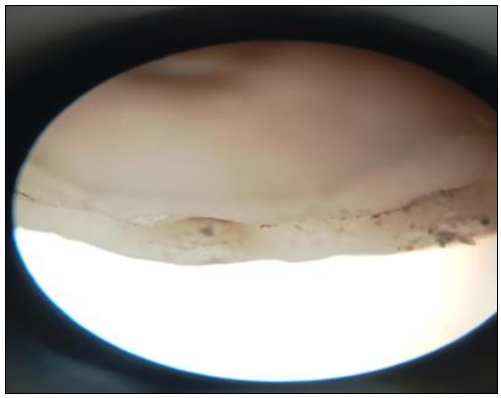

Fig 6: The micrograph (10X5X) showing marginal view of showing apical central nucleus in *C. rusci*

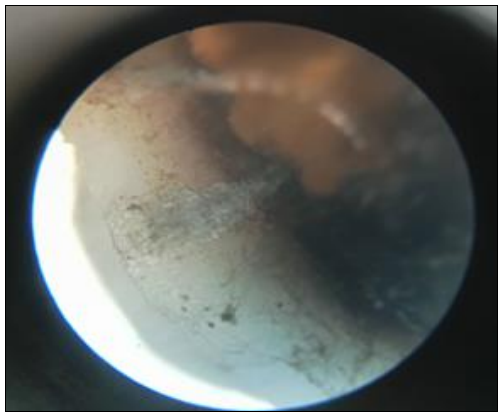

Fig 7: Micrograph (10X5X) inner marginal view of *C. rusci*.

The present study investigations concluded that in the region of Northern plains of India, as in Western Uttar Pradesh, India, the *Ceroplastes rusci* can become a serious insect pest of *Syzygium Sp*. and other plants, affecting adversely the fruit set, productivity and plant health. Due to the consequences of local climate change, atmospheric temperature and humidity fluctuations can be proven favourable for the growth and development of this wax-scale insect in the region. The population size was observed to increase in the month of July of 2023, when the region received good rains with increased humidity. Study findings will be sent to the Department of Horticulture, Agriculture and Forest of the Government of Uttar Pradesh and India.

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