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Comparative anatomy of Eruca sativa infected with *Albugo candida*

Ahmed H. Hamid, Khalid F. Darwish, Mohammed I. Khalil

Department of Biology, College of Education, University Of Garmian

Abstract

Eruca sativa (Arugula or Roket) is a widely distributed species. It has many economical, medical benefits. Growth abnormalities had observed among plants grown in Kalar city such as enlargement of Calyx in some plants. The aim of this study was to identify the reason beyond the abnormal growth and to decide whether the abnormality is due to fungal infection or no. To do so, we did collected different samples and took different sections from normal and abnormal plants. The sections were examined under different microscopes. The results indicated that the abnormal enlargements were due to the fungal infection (*Albugo candida*).

Introduction

Arugula or Rocket (*Eruca sativa*, family Brassicaceae) is an annual plant. It is widely distributed in Mediterranean areas. The plant has 10-100 cm tall. The root is erected taproot. The leaves are compound and stem has many branches (Gajra and Vinay 2014). Many countries use it as food or medicine. The antimicrobial and antifungal properties of *Eruca sativa* made it one of the most valuable plant in medicine (Shannon and Grieve, 1999; Helana et al, 2011; Saima et al, 2014). In the weed and agricultural management, the powder of *Eruca sativa* has been used as herbicide and had powerful effect on *Orobanche crenata* infected *Vicia faba* (El-Dabaa et.al, 2019). In addition, El-Wakeel et al, (2019) observed that extract of *Eruca sativa* could be used as bioherbicide to control two of *Pisum sativum's* weeds (*Phalaris minor* and *Beta vulgaris*). The bioherbicidal advantage of this plant make it safer to use by farmer instead of chemical herbicidal.

Some recent studies observed that the climate change (i.e. elevated temperature and CO2) levels increase form infection of *Eruca sativa* with fungal disease (ex. *Fusarium oxysporum*) (Chitarra et al, 2015). White rust (*Albugo candida*) is consider one of the infectious factor affecting *Eruca sative* (Latinović 2019) . *A. candida* is an obligate fungus and causes white rust on different parts of the infected plants (Saharan et al., 2014). The fungus belong to oomycete in the family Albuginaceae (Saharan and Verma, 1992). The main hosts of this fungus are species in the family of Brassicaceae. The pathogen causes significant damages in several Brassicaceae species such as reduction in plant defense and metabolism (Farr et al., 1989; Belhaj et al., 2017; Prince et al., 2019).

The plant are highly distributed in Kalar city/ Sulaimai province. Abnormality in growth among individuals of this plant has been noticed. The overall objective of this study was to investigate whether *Eruca sativa* in Kalar city are infected with *Albugo candida* or no. We do expect that the main factor of growth abnormality among plant individuals is due to fungal infection (*Albugo candida*) because many of the symptoms on the leaves and stem are revealed that the plant are infected with fungal disease. So, we need to do anatomical study to prove the infection.

Material and Methods

Samples were took from certain spots of wild *Eruca* sativum during three years (2017-2019) in Kalar city/Sulaimani province. The affected spots have been watched in order to determine the biological factors that affect the plant. To determine whether the plant has been infected by fungal disease (*Abugo candida*) or no, fresh samples have been transferred to the lab in the department of Biology at University of Garmian

in order to take anatomical sections of the infected and non-infected parts of the plant. The anatomical sections has been took using free hand section and the responsible factor has been detected. Furthermore, the infected parts have been compared with the non-infected one to observe and identify the infection. We documented the morphological characteristics by taking photographic pictures for the plant in the field. The pictures have been identified using Meiji RZ stereomicroscope and Biological microscope (Meiji MT4300L). Both microscopes were provided with camera (Canon kiss model).

Results and Discussion

The temporal field observation of the infected samples of *Eruca sativa* showed that the infection happened during late growth, especially after the emergence of floral buds. The floral parts were more infected than other parts. No infection seen in the stem and leaves. The infection was more obvious in the calyx than other floral parts. The results showed significant differences in morphological and anatomical appearance between infected and non-infected plant. Non-infected flowers showed dark veined petals and young fruits with honeybees visiting the flower (Plate1,A&B).

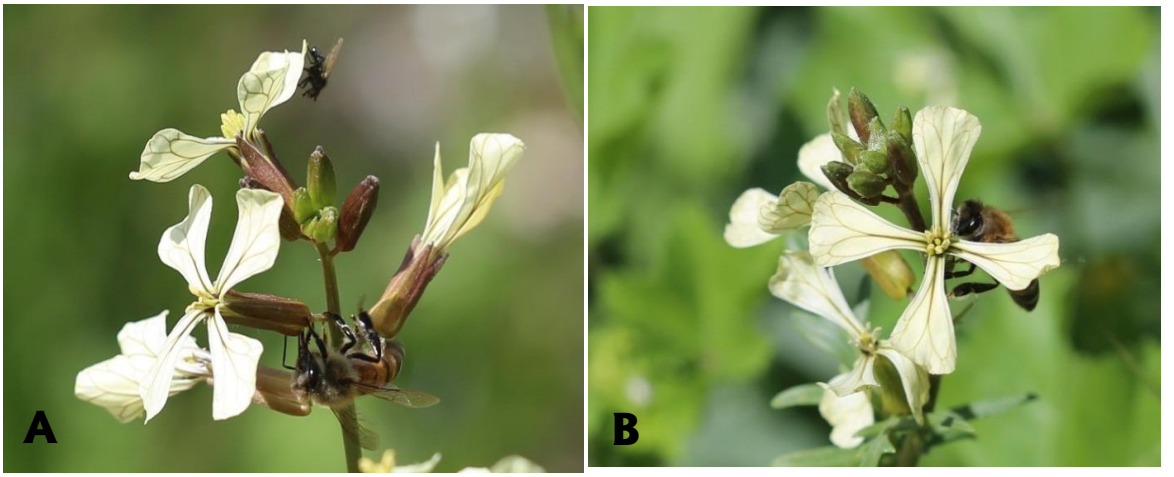

Plate 1. A& B: Non-infected flowers showed dark veined petals and young fruits with honeybees visiting the flower

The abnormal enlargement of the calyx leaves causes growth abnormality in that part, The size of enlargement makes the calyx of the infected plant to become ten folds larger than same part of the non-infected plant (Plate 2 A).The infected plant had abnormal floral parts such as swollen-like tumor of silique (Plate 2 B). The stem of the infected plant was abnormal especially near the infected floral complex (Plate 2 C).

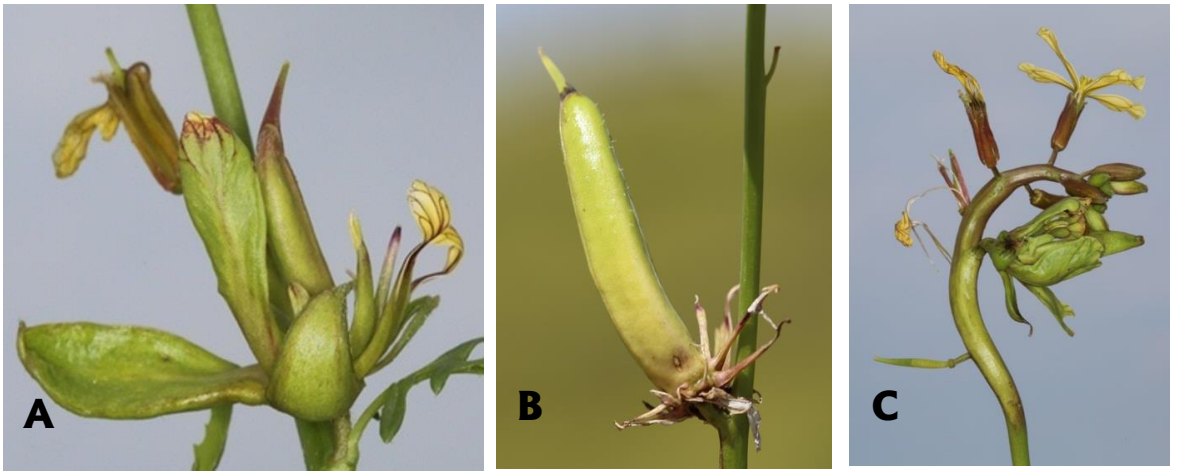

Plate 2 A; Infected floral complex, B; Swollen silique, C; stem effected by infected flower.

In comparison with non-infected plant (Plate 3 A-D) , The infected stem of *E. sativa* showed abnormal growth of green cortex in one side and pericycle on opposite side with early infection of pith (Plate 4 A). Late infection in cortex showed dense distribution of Oospore of *Albugo candida* (Plate 4 B)., High density of Oospore of *Albugo candida* occur in cross section of *Eruca sativa* silique , especially in the placenta (Plate 5 A&B).

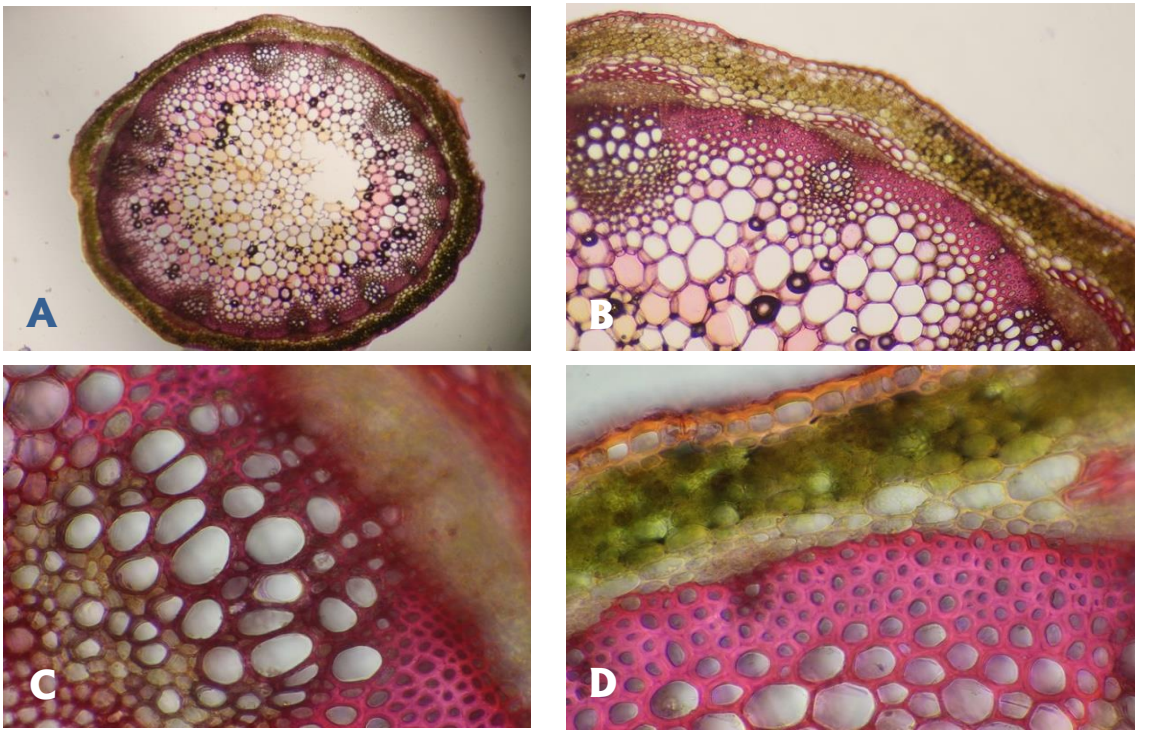

Plate 3: Non infected plant, A; Cross section of stem, B; part of Cross section of stem, C; Normal vascular Bundle , D; part of Cross section of stem show epidermis, Chlorenchyma of cortex, endoderm and pericycle.

The mesophyll of the infected sepals invaded by numerous Oospore of *Albugo candida* . Furthermore, many sporangia and oospores of *Albugo candida* seen in the cortex of the infected plant (Plate 6 A-D).

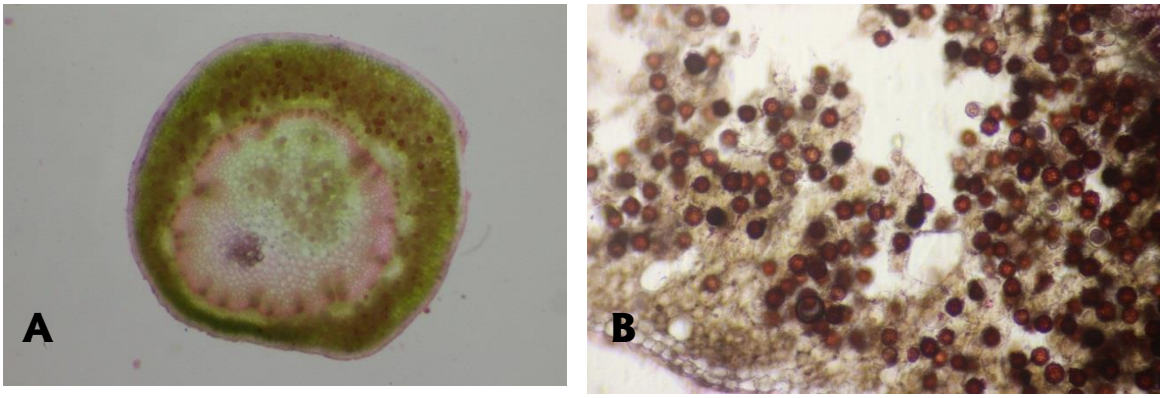

Plate 4: Infected plant, A; Cross section of stem, B; part of Cross section of stem showed destroyed tissue.

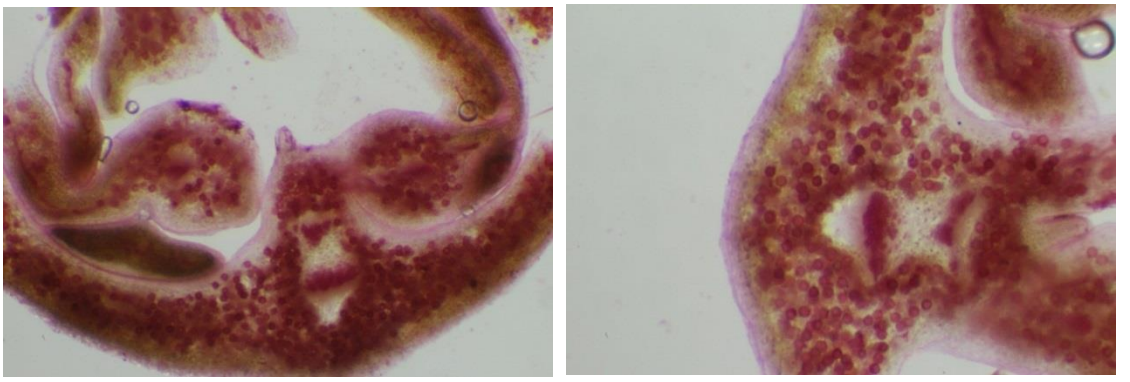

Plate 5 A,B High density of Oospore of *Albugo candida* in cross section of *Eruca sativa* silique.

Moreover, the infection spread to include the fruit part of the plant and sometimes the stalk and a few parts of stem beneath the stalk. In addition, we seen some intact plants adjacent to infected plants in the study site. We suggest that the consecutive visit of the honey bees to *Eruca sativa* could act as a vector *transferring the pathogen among infected and non-infected plants.*

Conclusion

This study showed the importance of monitoring and studying the growth of wild plants especially those that have medical, economical and ecological impacts, such as *E. sativa*. Fungal infection is one of the factors that influence the growth of *E. sativa*. Many studies are needed to answer the following questions: 1) how the infected plant got the fungal infection? 2) Does the infection affect the actions or the metabolism of the plant? 3) What are the ecological consequences of such infection?. Therefore, we recommend doing ecological, molecular, and anatomical studies in the future to address the questions above.

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