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Biology, disease development, distribution and control of rust pathogen *Uromyces viciae-fabae*

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Abstract

Uromyces is an important plant pathogenic genus of rust fungi (Pucciniales, Basidiomycota). *Uromyces fabae* is one of the major species of this rust genus that affects the plant family Fabaceae. This rust fungus is autoecious in nature, produces aeciospores, urediospores and teliospores found on the surface of the host plant. This fungus has worldwide in distribution showed maximum distribution in various countries of Europe followed by Asia, Oceania and Australia. The majority of occurrences of this fungus was observed on Fabaceae whereas few cases on Asteraceae, Cucurbitaceae & Polygonaceae. Being a major pathogen on family Fabaceae, *U. viciae-fabae* diseases can be controlled by cultural and chemical methods. This study is focused on biology, disease development, distribution and control of rust pathogen *Uromyces viciae-fabae*.

Keywords – macrocyclic – pathogens – Pucciniales – rust diseases

Introduction

Uromyces is a genus of rust fungi belongs to the family Pucciniaceae. It is considered as second largest genus after *Puccinia*. The species of *Uromyces* differ morphologically from species of *Puccinia* only by having one-celled teliospores (Cummins & Hiratsuka 2003). The genus is macrocyclic in nature, producing as many as five dissimilar stages in their life cycles. The species of the *Uromyces* are found distributed all over the globe on both monocot and dicot plants. These fungi can infect all categories of plants i.e. herbs, shrubs and trees, however, more than 900 species of herbaceous plants are found infected by them. The plant families like Fabaceae and Asteraceae are reported to be affected mainly by species of *Uromyces*, however, these fungi are found on other plant species also (Sánchez & Piepenbring 2014).

Among species of *Uromyces*, *U. fabae* is an important rust pathogen known to cause rust disease on pea (*Pisum sativum*). It is described as autoecious rust with aeciospores, urediospores and teliospores found on the surface of host plant (Arthur & Cummins 1962, Gaumann 1998). This rust was firstly reported by D.C.H. Persoon in 1801, which was later renamed as *Uromyces fabae* (Pers) de Bary by de Bary in 1879. Currently accepted name of *U. fabae* is *Uromyces viciae-fabae* (Pers.) J. Schröt (Index fungorum). Thereafter, many *forma speciales* (*f.* sp.) of this genus were described after the addition of number of hosts. It mainly affects the plant family Fabaceae, however, found on other plant families also. It is one of the major rust pathogens causing diseases

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on variety of plants. Several important crops such as Broad bean (*Vicia faba*), Pea (*Pisum sativum*), Lentil (*Lens culinaris*), are found affected by these fungi. More than 50 species of *Vicia* and about 20 species of *Lathyrus* showed the diseases symptoms caused by *U. vicia-fabae* (Conner & Bernier 1982). The rust fungi produce typical reddish brown, yellow rust-like pustules mainly on the stem and leaves. The infection of these rusts causes mainly defoliation, drying and even death of the infected plants. Decreased photosynthetic rate along with loss in net yield of the plants are also associated with infection of these fungi.

Uromyces vicae-fabae is placed in one of the largest phylum Basidiomycota along with smut fungi and macro fungi. It is macrocyclic and autoecious in nature, affecting number of crops along with other non-agricultural hosts. These fungi affect mostly the plants belonging to the family Fabeaceae and causing great loss in the form of growth and yield. It is found distributed all over the world and cause mild to severe infection on pea (*Pisum sativum*), lentil (*Lens culinaris*), alfalfa (*Medicago sativa*), broad bean (*Vicia faba*) and faba bean (*Vicia faba* L.) (Conner & Bernier 1982, Xue & Warkentin 2002, Sadravi et al. 2007). Some species of these fungi offer hereroecious life cycle mode and limited growth upto epidermal cells. It offers a great possibility to further study on the life cycle of these fungi. However, the present study focused on biology, disease development, distribution and control of *Uromyces viciae-fabae,* an important rust pathogen.

A species of *Uromyces* namely, *U. fabae* was described as pea rust pathogen causes great loss in growth and yield. It is described as autoecious rust with aeciospores, urediospores and teliospores found on the surface of host plant (Arthur & Cummins 1962, Gaumann 1998). It was firstly reported by D. C. H. Persoon in 1801 and later renamed as *Uromyces fabae* (Pers) de Bary Thereafter, many *forma speciales* (*f.* sp.) of this genus were described after the addition of number of hosts. The *f.* sp. *viciae-fabae* was described by Kispatic (1949) while including *Vicia fabae* in the host range of *Uromyces. Uromyces vicia-fabae* is an important species of the genus infecting number of plants throughout the globe.

Biology of *Uromyces viciae-fabae*

The rust of pea caused by *Uromyces fabae* (*Uromyces viciae-fabae*) was first reported by Persoon in 1801. Later on, de Bary in 1862 altered the genus and renamed it as *Uromyces fabae* (Pers.) de Bary, which was subsequently renamed as *Uromyces viciae-fabae*. This rust pathogen is autoecious in nature, with aeciospores, urediospores and teliospores found on a similar host plant (Arthur & Cummins 1962, Gaumann 1998). The fungus is classified into nine formal specials, each with a host range restricted to a few species. The peridium of aecium in *Uromyces viciae fabae* is short, whitish and cup shaped. The aeciospores are round to angular or elliptical, yellow in colour with fine warts. They measure 14-22 µm in diameter. The uredospores are round to ovate, light brown echinulate with 3-4 germ pores and measure 20-30 × 18-26 microns (µm). The teliospores are sub globose to ovate, thick walled, with straightened apex, smooth, single celled, pedicellate and about 25-38 × 18-27 microns (µm) in size (Singh 1973). Prasada & Verma (1948) working with *Uromyces fabae* from lentil found that infection with aeciospores at lower temperatures (17-26°C) brings the arrangement of secondary aecia, while at 25°C the infection causes expansion of uredia. Infection is not happening by aeciospores at 30°C. Ideal temperatures for germination of uredospores is 16-22°C, while germination doesn't happen at 28-29°C. The teliospores of lentil rust can sprout at 12-22°C.

Two species of *Uromyces viciae-fabae* have been found to cause rust of pea. The pea rust caused by *U. pisi* (Persoon) de Bary, has been reported from various European nations. Another species *U. fabae* (Pers.) de Bary (*Uromyces viciae-fabae*) has been found to cause pea rust (Butler 1918, Prasada & Verma (1948). Among these, *Uromyces viciae-fabae* is reported to cause significant yield losses (56.8 to 100%) particularly in temperate climate conditions (Upadhyay & Singh 1994, Kushwaha et al. 2010). Apart from pea, this rust pathogen causes significant damage in terms of quality and quantity on faba bean and lentil (Sharma 1998, Beniwal et al. 1993).

Life cycle

Uromyces viciae-fabae is a macrocyclic rust fungus that exhibits every one of the spore structures known for the Uredinales and autoecious in nature i.e. all spores are formed by single host (Hahn et al. 1997). After overwintering on crop remains left after harvesting, diploid teliospores develop in the spring with the production of a metabasidium. After meiosis, metabasidium produces four haploid basidiospores with two various mating types. These spores start germination after finding suitable host surface and produce disease structures. Firstly, it produces pycnia of various mating types which contains pycniospores. These pycniospores get exchanged between among pycnia of various mating types. After spermatization, dikaryotization happens in early aecial stage. After separating, aecia produce dikaryotic aeciospores which germinate and forms disease structures. The uredia are developed from aecia which produce urediospores. Urediospore is the major asexual spore type of rust fungi produced in massive amount through repeated contamination of host plants throughout the summer. Urediospores are scattered aerially and can travel many kilometers (Brown & Hovmoller 2002). The teliospores occur in the same sources as the uredia and develop from the same mycelium (Singh 1973). The general macro and microscopic structures produced by this rust pathogen are depicted in (Figs 1, 2, 3).

Symptoms

The primary symptoms appear with the development of aecia. Yellow aecia first appear on the under surface of the different plant parts like leaves, stems, and petioles. These aecia are turned yellowish firstly, which later turned brown uredia. The uredospores produced by uredia appear as light brown powder. All four stages develop on the host's green parts; including the pods. Telia and Teliospores emerge from the same sources as uredia and develop from the same mycelium (Singh 1973). Thatcher (1939) investigated the impact of *U. vicae-fabae* (*U. fabae*) on pea and revealed that this fungus increased the permeability of the host cell by secreting some metabolites, which proved fatal in the end. Hahn et al. (1977) also reported that a putative amino acid transporter was specifically expressed in the haustoria of the rust fungus *Uromyces vicae-fabae,* which may be the cause of increased permeability of the host cells. Protein synthesis during differentiation of the bean rust fungus was reported by Dekhuijzen & Staples (1968) and Huang & Staples (1982). Staples & Stahmann (1964) also reported a change in protein and several enzymes in susceptible bean leaves after rust infection. The general symptoms produced by *U. vicae-fabae* on different plant hosts are presented in (Figs 1, 2, 3).

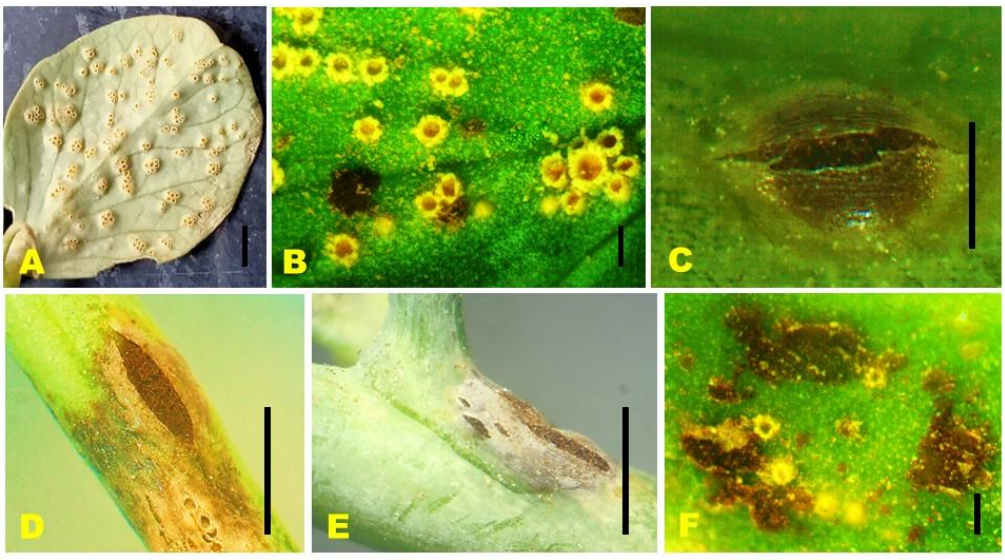

Fig. 1 – *Uromyces viciae-fabae* on *Pisum sativum.* A-B Aecia. C-D Uredia. E-F Telia. Scale Bar: A-F = 0.5 mm.

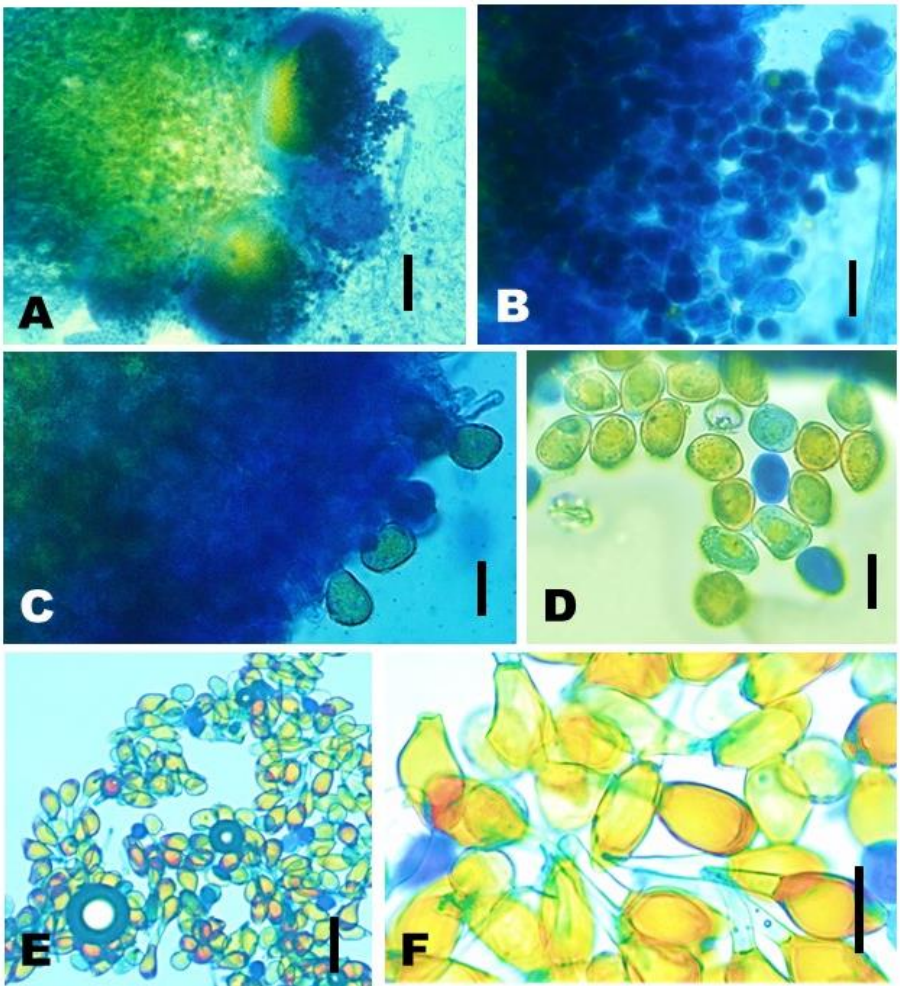

Fig. 2 – *Uromyces viciae-fabae* on *Pisum sativum*. A Aecia. B Aeciospores. C Uredia. D Urediospores. E-F Teliospores. Scale Bar: A-F = 20 µm.

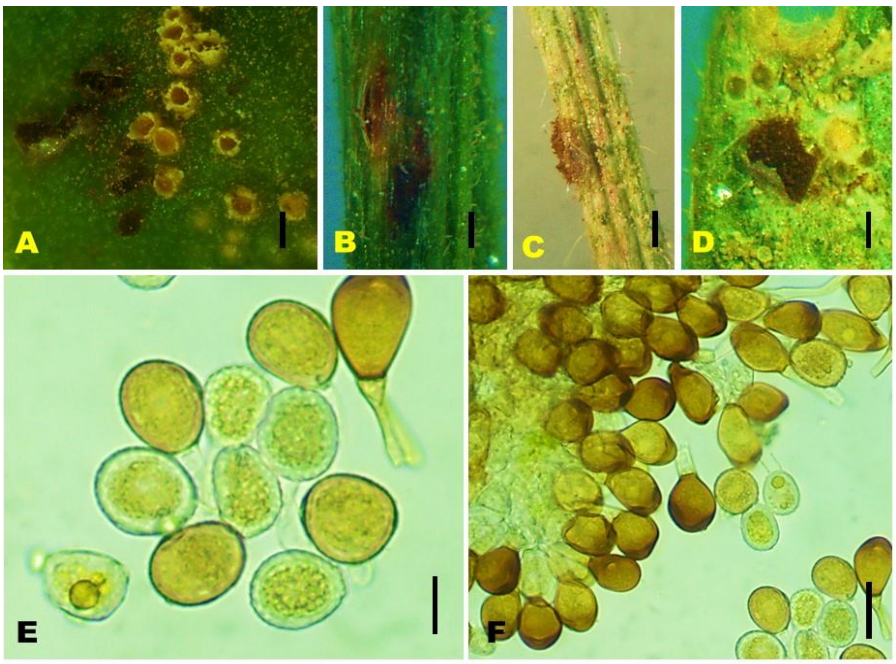

Fig. 3 – *Uromyces viciae-fabae* on *Vicia faba*. A Aecia. B-C. Uredia. D Telia. E Urediospores. F Teliospores. Scale Bar: A-D = 1 mm, E-F = 20 µm.

Distribution of the pathogen

In order to understand the worldwide distribution of *U. vicae-fabae,* total 226 randomly selected records of this rust pathogens were analyzed. It was observed that the rust pathogen *U. vicae-fabae* has a wide distribution with respect to geographical conditions and host. When we compare continental distribution, these fungi were showed maximum distribution in various countries of Europe. Similarly, their distribution was found highest in Asia after Europe while minimum in Oceania and Australia. After analyses of distribution on host plants, majority of occurrences was observed on Fabaceae (97%), while very less on Cucurbitaceae (2%) and on Asteraceae & Polygonaceae (1% each). These results of occurrence of this rust fungi on plant family Fabaceae justify the name of the pathogen as *Uromyces vicae-fabae*. The detailed information on the occurrence of *U. vicae-fabae* with respect to plant host and country is presented in Table 1 and Figs 4, 5.

Table 1 Host range and distribution of *Uromyces vicae-fabae*.

Host	Distribution	References
Cicer arietinum	France	Guyot (1957)
Cicer arietinum	India	Pande & Rao (1998), Patel (1934), Sydow & Butler (1907, 1912)
Citrullus vulgaris	Mexico	Alvarez (1976)
Cucurbita pepo	Mexico	Alvarez (1976)
Ervum lens	Bulgaria, Cyprus, France, Germany, Greece, Hungary, India, Palestine, Portugal, Russia, Sweden, Switzerland, Turkey	Guyot (1957)
Ervum ervilia	Cyprus, France, Malta, Russia	Guyot (1957)
Ervum hirsutum	Austria, Belgium, France, Germany, Poland, Portugal, Romania, Spain	Guyot (1957)
Ervum tetraspermum	China, Hungary, Japan	Guyot (1957)
Faba bona	USSR	Azbukina (1984)
Faba vulgaris	Africa, Algeria, Argentina, Australia, Austria, Azerbaijan, Bermuda, Bolivia, Brazil, Bulgaria, Caucasus, Chile, China, Colombia, Cook Islands, Cyprus, Czech Republic, Denmark, Finland, France, Georgia, Germany, Greece, Guatemala, Hungary, India, Iran, Italy, Japan, Latvia, Libya, Mexico, Morocco, Mozambique, New Zealand, Norway, Palestine, Peru, Poland, Portugal, Romania, Russia, Spain, Sudan, Sweden, Switzerland, Tanzania, Tasmania, Tunisia, Turkey, Ukraine, United Kingdom, United States, Uruguay, Venezuela, Yugoslavia, Zimbabwe	Guyot (1957)
Lathyrus alpestris subsp. *friedrichstalii*	Bulgaria	Denchev (1995)
Lathyrus aphaca	India	Pande & Rao (1998)
Lathyrus aphaca	India	Sarbhoy & Agarwal (1990), Pande & Rao (1998)
Lathyrus arizonicus	Arizona	Gilbertson et al. (1979), Yohem et al. (1985), Gilbertson & McHenry (1969)
Lathyrus bijugatus	Washington	Hotson (1925)
Lathyrus bijugatus	Ldaho, Washington	Shaw (1973)
Lathyrus bolanderi	California	Anonymous (1970), Blasdale (1919)
Lathyrus cicera	Morocco, Portugal	Guyot (1957), Gonzalez Fragoso (1918)

Table 1 Continued.

Host	Distribution	References
Lathyrus clymenum	Italy	Guyot (1957)
Lathyrus coriaceus	Utah	Garrett (1937)
Lathyrus davidii	China	Tai (1979), Guyot (1957)
Lathyrus davidii	China, Japan	Guo & Wang (1986), Hiratsuka et al. (1992), Chung et al. (2004)
Lathyrus decaphyllus	New Mexico	Gilbertson et al. (1979)
Lathyrus digitatus	Greece	Pantidou (1973)
Lathyrus eucosmus	Arizona	Gilbertson et al. (1979)
Lathyrus eucosmus	Arizona	Yohem et al. (1985), Gilbertson & McHenry (1969)
Lathyrus hirsutus	Italy	Guyot (1957)
Lathyrus humilis	Russia	Guyot (1957), Benua & Karpova-Benua (1973)
Lathyrus humilis	China, Russia, USSR	Zhuang (2005a), Gjaerum (1996), Azbukina (1984)
Lathyrus japonicus	Alaska, Korea	Cash (1953), Cho & Shin (2004)
Lathyrus jepsonii	California	Blasdale (1919)
Lathyrus komarovii	China	Guo & Wang (1986), Zhuang (2005b)
Lathyrus laetivirens	Arizona	Gilbertson et al. (1979)
Lathyrus lanszwertii	Utah	Gilbertson et. al. (1979)
Lathyrus lanszwertii	Oregon, Washington	Shaw (1973)
Lathyrus lanszwertii var. *aridus*	California	Cooke (1951, 1955)
Lathyrus latifolius	Algeria, Portugal	Guyot (1957), Gonzalez Fragoso (1918)
Lathyrus leucanthus	Arizona, Ldaho, Wyoming	Yohem et al. (1985), Gilbertson & McHenry (1969), Shaw (1973)
Lathyrus linifolius	Germany	Braun (1982)
Lathyrus littoralis	California	Anonymous (1970)
Lathyrus magellanicus	Chile	Guyot (1957)
Lathyrus maritimus	Alaska, Japan	Sprague (1955), Anderson (1952), Guyot (1957), Ito (1922, 1950)
Lathyrus montanus	Portugal	de Sousa Dias et al. (1987)
Lathyrus montanus	Norway, Poland,	Gjaerum (1974), Adamska (2001), Mulenko et al. (2008)
Lathyrus myrtifolius	Lowa	Gilman & Archer (1929)
Lathyrus nevadensis	California	Anonymous (1970)
Lathyrus nevadensis	Oregon, Washington	Shaw (1973)
Lathyrus niger	Denmark, Norway, Poland, Sweden, Ukraine	Hylander et al. (1953), Kucmierz (1965), Gutsevich (1952)
Lathyrus niger subsp. *niger*	Bulgaria	Negrean & Denchev (2000)
Lathyrus nissolia	Spain	Guyot (1957)
Lathyrus obovatus	Washington	Hotson (1925)
Lathyrus ochroleucus	South Dakota, Utah	Mankin (1969), Garrett (1937)
Lathyrus ochroleucus	Ldaho	Shaw (1973)
Lathyrus odoratus	India, Pakistan	Ahmad (1956), Kapooria & Sinha (1966), Khalid et al. (1993), Pande & Rao (1998)

Table 1 Continued.

Host	Distribution	References
Lathyrus odoratus	India	Sarbhoy & Agarwal (1990), Pande & Rao (1998)
Lathyrus paluster	Finland	Liro (1908)
Lathyrus palustris	California, China, Finland, France, Germany, Japan, Russia, Spain, Sweden, United Kingdom, United States,	French (1989), Tai (1979), Guyot (1957), Ito (1922, 1950), Hylander et al. (1953), Gonzalez Fragoso (1917)
Lathyrus palustris var. *linearifolius*	China, Japan	Tai (1979), Ito (1950)
Lathyrus palustris var. *linearifolius*	China, Japan	Guo & Wang (1986), Hiratsuka et al. (1992)
Lathyrus palustris var. *pilosus*	Japan, Russia	Guyot (1957), Benua & Karpova-Benua (1973)
Lathyrus pauciflorus	Washington	Hotson (1925)
Lathyrus pauciflorus	Ldaho, Montana, Oregon, Washington	Shaw (1973)
Lathyrus polymorphus	Wyoming	Gilbertson et al. (1979)
Lathyrus polyphyllus	California, Washington	Anonymous (1970), Hotson (1925)
Lathyrus polyphyllus	Oregon, Washington	Shaw (1973)
Lathyrus pratensis	United Kingdom	Grove (1913)
Lathyrus pratensis	Bulgaria, China, Russia	Denchev (1995), Cao et al. (2000)
Lathyrus pratensis var. *pubescens*	France	Guyot (1957)
Lathyrus roseus	Armenia	Simonyan (1981)
Lathyrus sativus	India	Pande & Rao (1998), Patel (1934), Sydow & Butler (1907, 1912), Mishra (1969), Mishra & Khare (1969)
Lathyrus sativus	India, Russia	Pande & Rao (1998), Ryzhkin & Levkina (2004)
Lathyrus sp.	Alaska, California, Chie, Italy, Sicily, Oregon, Russia	Mishra (1969), Mishra & Khare (1969)
Lathyrus sp.	India, Italy, Sicily	Sarbhoy & Agarwal (1990), Greuter et al. (1991)
Lathyrus spaericus	India	Patel (1934), Sydow & Butler (1907, 1912)
Lathyrus sphaericus	India	Guyot (1957), Pande & Rao (1998)
Lathyrus sphaericus	India	Sarbhoy & Agarwal (1990), Pande & Rao (1998)
Lathyrus strictus	California	Anonymous (1970)
Lathyrus sulphureus	California, Washington	Anonymous (1970), Hotson (1925)
Lathyrus sulphureus	Oregon, Washington	Shaw (1973)
Lathyrus sylvestris	France, Germany, North Dakota, Poland	Guyot (1957), Mankin (1969)
Lathyrus sylvestris	Bulgaria, Poland	Denchev (1995)
Lathyrus torreyi	California	Anonymous (1970), Blasdale (1919)
Lathyrus torreyi	Oregon	Shaw (1973)
Lathyrus tuberosus	Bulgaria, Denmark, France, Italy, Romania,	Guyot (1957), Hylander et al. (1953)

Table 1 Continued.

Host	Distribution	References
Lathyrus tuberosus	Bulgaria, Norway, Turkey	Denchev (1995), Gjaerum (1974), Bahcecioglu & Kabaktepe (2012)
Lathyrus utahensis	Utah	Garrett (1937)
Lathyrus venetus	Bulgaria	Denchev (1995)
Lathyrus venosus	Lowa, North Carolina	Gilman & Archer (1929), Wolf et al. (1938)
Lathyrus venosus	Lowa	Tiffany & Knaphus (1984)
Lathyrus vernus	Denmark, Finland, Norway, Poland, Russia, Sweden	Hylander et al. (1953), liro (1908), Kucmierz (1965), Gasich et al. (1999)
Lathyrus vestitus	Oregon	Shaw (1973)
Lathyrus violaceus	California	Blasdale (1919)
Lens culinaris	Brazil, China, Greece, India, Sweden	Tai (1979), Pantidou (1973), Khare (1991), Hylander et al. (1953)
Lens esculenta	Bulgaria, Chile, Cyprus, Nepal	Bobev (2009), Mujica & Oehrens (1967), Georghiou & Papadopoulos (1957), Singh (1968), Patel (1934), Sydow & Butler (1907, 1912) Sarbhoy & Agarwal (1990)
Lens esculenta	India, Israel, Kenya, Turkey	Pande & Rao (1998), Savchenko et al. (2014), Nattrass (1961)
Melilotus officinalis	Netherlands	Guyot (1957)
Orobus aureus	Russia	Guyot (1957)
Orobus luteus	Asia, Austria	Guyot (1957)
Orobus luteus var. *orientalis*	Kazakhstan, Russia, Siberia	Guyot (1957)
Orobus niger	Austria, Czech Republic, Denmark, France, Germany, Hungary Norway Italy Poland, Romania, Russia, Sweden, Switzerland, Syria, Ukraine	Guyot (1957)
Orobus niger	Romania	Savulescu (1953)
Orobus sp.	Russia, Siberia	Guyot (1957)
Orobus tuberosus	Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Norway, Poland, Romania, Russia, Siberia, Spain, Sweden, Switzerland, United Kingdom	Guyot (1957)
Orobus variegatus	Austria	Guyot (1957)
Orobus vernus	Austria, Bulgaria, Czech Republic, Denmark, Estonia, Finland, Georgia, Republic of, Germany, Hungary, Italy, Lapland, Norway, Poland, Romania, Russia, Sweden, Switzerland, Ukraine, Yugoslavia	Guyot (1957), Savulescu (1953), Ryzhkin & Levkina (2004)
Orobus vernus var. *alatus*	Russia	Guyot (1957)
Orobus vernus var. *frolovii*	Russia	Guyot (1957)
Orobusalpestris	Russia, Siberia	Guyot (1957)
Orobuslathyroides	Russia, Siberia	Guyot (1957)
Phaca australis	Italy	Guyot (1957)
Phaseolus sp. *Papua*	New Guinea	Shaw (1984)
Phaseolus vulgaris	Kenya	Nattrass (1961)

Table 1 Continued.

Host	Distribution	References
Pisum arvense	India, Italy, Japan, Morocco	Guyot (1957), Pande & Rao (1998), Ito (1950), Mitter & Tandon (1930)
Pisum arvense	India	Sarbhoy & Agarwal (1990), Pande & Rao (1998)
Pisum sativum	Afghanistan, brazil, California, Canada, British Columbia, Manitoba, China, Cyprus, Denmark, Greece, India	Guyot (1957), Nema & Mishra (1965), Rangaswami et al. (1970)
Pisum sativum var. *arvense*	China, Texas	Tai (1979), Anonymous (1960)
Pisum sativum var. *arvense*	Italy, Sicily	Greuter et al. (1991)
Pisum sp.	Massachusetts	Dixon et al. (2010)
Rudbeckia laciniata var. *hortensis*	Lowa	Gilman & Archer (1929)
Rumex angustifolius	Canary Islands	Jorstad (1962)
Vicia biesnnis	India	Kapooria & Sinha (1966)
Vicia americana	California, Missouri, Montana, Washington	Cooke 1951, Anonymous (1970), Cooke (1955), French (1989), Maneval (1937), Gilbertson et al. (1979), Anonymous (1960), Hotson (1925)
Vicia americana var. *americana*	Arizona	Yohem et al. (1985)
Vicia americana var. *Americana Colorado*	America	McCain et al. (1990)
Vicia amoena	Japan, Russia	Ito (1950), Benua & Karpova-Benua (1973)
Vicia amoena var. *oblongifolia*	China, Japan	Tai (1979), Ito (1950)
Vicia amoena var. *oblongifolia*	China	Guo & Wang (1986)
Vicia amoena var. *sachalinensis*	Japan	Guyot (1957)
Vicia amurensis	China	Zhuang (2005b)
Vicia angustifolia	Austria	Guyot (1957)
Vicia articulata	France	Guyot (1957)
Vicia atropurpurea	Portugal	Guyot (1957)
Vicia atropurpurea	Canary Islands	Gjaerum (1974)
Vicia biebersteiniana	Romania	Guyot (1957)
Vicia biebersteiniana	Romania	Savulescu (1953)
Vicia biennis	India	Pande & Rao (1998)
Vicia biflora	Italy	Guyot 1957.
Vicia bitanya	Spain	Guyot 1957, Gonzalez Fragoso (1917)
Vicia bithynica	France, Italy, United Kingdom	Guyot (1957)
Vicia bungei	China	Tai (1979)
Vicia canescens	Germany	Guyot (1957)
Vicia cassubica	Austria, Czech Republic	Guyot (1957)
Vicia cassubica	Bulgaria	Denchev (1995)
Vicia ciliatula	Caucasus	Guyot (1957)
Vicia cracca var. *japonica*	Japan	Guyot (1957), Ito (1950)
Vicia cracca var. *japonica*	Japan	Hiratsuka et al. (1992)
Vicia deflexa	Japan	Ito (1950)

Table 1 Continued.

Host	Distribution	References
Vicia disperma	France, Portugal, Spain	Guyot (1957), Gonzalez Fragoso (1917, 1918)
Vicia dumetorum	Czech Republic, Hungary, Ukraine	Guyot (1957)
Vicia dumetorum	Poland	Mulenko et al. (2008)
Vicia ervilia	Cyprus	Georghiou & Papadopoulos (1957)
Vicia ervillia	India	Pande & Rao (1998), Kapooria & Sinha (1966)
Vicia ervillia	India	Pande & Rao (1998)
Vicia exigua	California	Anonymous (1970), French (1989)
Vicia faba	India	Kapooria & Sinha (1966)
Vicia fauriae	Japan	Guyot (1957), Ito (1922, 1950)
Vicia fauriae	Japan	Hiratsuka (1973)
Vicia gracilis	India	Kapooria & Sinha (1966), Pande & Rao (1998)
Vicia grandiflora	Greece, Romania, Yugoslavia	Pantidou (1973), Guyot (1957)
Vicia hirsuta	China, India	Tai (1979), Pande & Rao (1998)
Vicia hirusuta	India	Kapooria & Sinha (1966)
Vicia hybrida	Greece	Pantidou (1973)
Vicia japonica	Japan	Guyot (1957), Ito (1950)
Vicia kulingana	China	Guyot (1957)
Vicia kulingana	China	Guo & Wang (1986)
Vicia lathyroides	Austria, France, Sweden, Spain	Guyot (1957), Gonzalez Fragoso (1914, 1917), Hylander et al. (1953)
Vicia lutea	France, Italy, United Kingdom	Guyot (1957)
Vicia lutea	United Kingdom	Henderson (2000)
Vicia lutea var. *hirta*	France	Guyot (1957)
Vicia macrocarpa	Norway	Gjaerum (1974)
Vicia megalotropis	Russia, Siberia	Guyot (1957)
Vicia melanops	France	Guyot (1957)
Vicia monanthos	Canary Islands	Gjaerum & Sunding (1986)
Vicia multicaulis	Russia, Siberia	Guyot (1957)
Vicia narbonensis	Bulgaria, France, India	Guyot (1957), Pande & Rao (1998)
Vicia narbonensis	Ausrtralia, India, Turkey	Cook & Dube (1989), Pande & Rao (1998), Bahcecioglu & Kabaktepe (2012)
Vicia narbonensis var. *serratifolia*	Romania	Guyot (1957)
Vicia nipponica var. *capitata*	Japan	Guyot (1957)
Vicia nipponica var. *capitata*	Japan	Hiratsuka et al. (1992), Chung et al. (2004)
Vicia nummularia	China	Guo & Wang (1986), Zhuang (2005b)
Vicia onobrychioides	Morocco, Switzerland	Guyot & Malencon (1957), Guyot (1957)
Vicia oroboides	Italy	Guyot (1957)
Vicia orobus	France	Guyot (1957)
Vicia pallida	Russia, Siberia	Guyot (1957)

Table 1 Continued.

Host	Distribution	References
Vicia pallida var. *japonica*	Japan	Guyot (1957), Ito (1950)
Vicia pannonica	Bulgaria, Yurope	Denchev (1995), Maier et al. (2007)
Vicia peregrina	Morocco	Guyot (1957)
Vicia pinetorum	Greece	Pantidou (1973)
Vicia pisiformis	Austria, Germany, Switzerland	Guyot (1957)
Vicia pseudocracca	Libiya	El-Buni & Rattan (1981)
Vicia pseudo-orobus	Japan	Guyot (1957), Ito (1950)
Vicia pseudo-orobus	China, Japan	Zhuang (2005b), Chung et al. (2004)
Vicia pulchella	Arizona	Yohem et al. (1985), Gilbertson & McHennry (1969)
Vigna radiata	India	Singh (1973)
Vicia sativa subsp. *macrocarpa*	Greece	Pantidou (1973)
Vicia sativa subsp. *nigra*	Greece	Pantidou (1973)
Vicia sativa var. *cordata*	Morocco	Guyot & Malencon (1963)
Vicia sativa var. *segetalis*	Romania	Savulescu (1953)
Vicia segetalis	France, Italy, Poland, Romania	Guyot (1957)
Vicia sepium var. *montana*	Romania	Guyot (1957)
Vicia sepium var. *montana*	Romania	Savulescu (1953)
Vicia sepium var. *oxyphylla*	Romania	Guyot (1957)
Vicia sepium var. *oxyphylla*	Romania	Savulescu (1953)
Vicia serratifolia	Romania	Guyot (1957)
Vicia serratifolia	Romania	Savulescu (1953)
Vicia sibthorpii	Greece	Pantidou (1973), Guyot (1957)
Vicia sparsifolia	Arizona	Gilbertson & McHennry (1969)
Vicia sylvatica	Poland	Mulenko et al. (2008)
Vicia tanakae	Japan	Guyot (1957), Ito (1950)
Vicia tanakae	Japan	Hiratsuka (1973)
Vicia tenuifolia	Czech Republic, Romania, Russia	Guyot (1957)
Vicia tenuifolia	Bulgaria, Poland, Romania	Denchev (1995), Mulenko et al. (2008), Savulescu (1953)
Vicia tetrasperma	India, Japan	Pande & Rao (1998), Ito (1922)
Vicia tetrasperma	India, Poland	Pande & Rao (1998)
Vicia tibetica	China	Adamska (2001), Zhuang (2005b)
Vicia unijuga	China, Japan, Russia	Tai (1979), Guyot (1957)
Vicia unijuga	China, Japan	Guyot (1957), Zhuang(2005b)
Vicia varia	Bulgaria	Denchev (1995)
Vicia venosa	Japan, Russia, Siberia	Guyot (1957), Ito (1922)
Vicia villosa	China, Hungary, Poland, Romania, Ukarine	Tai (1979)
Vicia villosa	Bulgaria, China, Turkey, Germany, Poland, Romania	Denchev (1995), Guo & Wang (1986), Cao et al. (2000)
Vicia villosa subsp. *microphylla*	Greece	Pantidou (1973)
Vicia villosa subsp. *varia*	Greece	Pantidou (1973)
Vicia villosa var. *wilczekii*	Morocco	Guyot (1957)

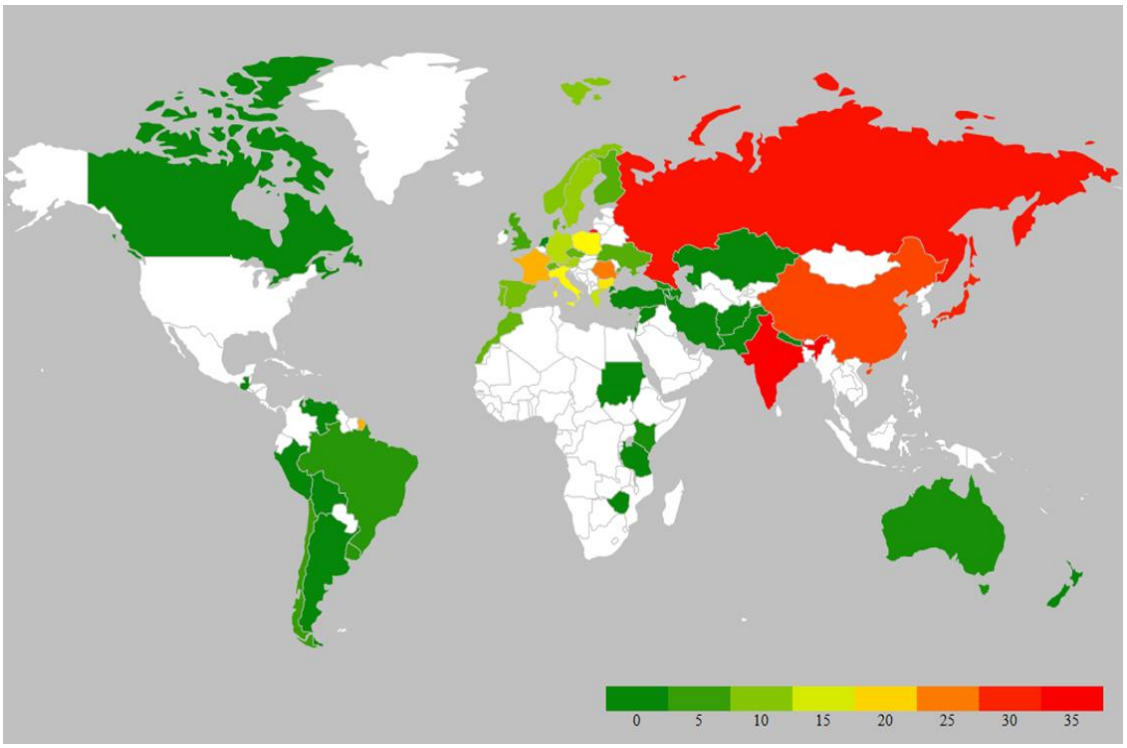

Fig. 4 – Geographical Heat Map showing distribution of *Uromyces viciae-fabae*.

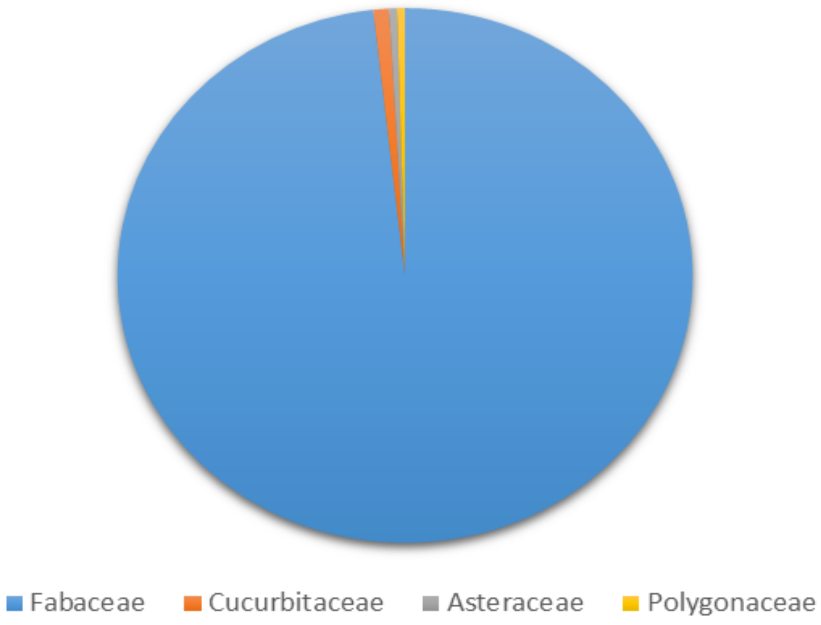

Fig. 5 – Distribution of *Uromyces viciae-fabae* on different plant families.

Control of rust diseases of *Uromyces viciae-fabae*

The cultural methods and fungicides can be used to control rust diseases of *U. viciae-fabae*. The most commonly used cultural control methods include collecting and burning or burying of infected plant remains. Use of suitable crop rotation with non-leguminous crops is another method of cultural control (Upadhyay et al. 2019). Delayed sowing is also reported as one of the important control methods (Singh & Singh 1996, Rai & Gupta 2003). In addition, mixed cropping is another useful practice to control this rust disease. The supply of organic matter in the form of farmyard manure or compost to the soil, improves the soil health and promotes to pea plant combat against various diseases including rust disease (Upadhyay et al. 2019). Besides cultural control, use of

certain chemicals proved useful to control rust disease of pea. Dusting of Sulphur 80% WP @ 1.252 Kg in 300- 400 l water per acre can reduce rust infection. Similarly, use of Sulphur 85% DP @ 6–8 Kg per acre can also control this rust pathogen (Ayub et al. 1996). Different fungicides like Dithane M-45, Indofil M-45, Karathane, and Sulfex are also reported to control this rust pathogen in severe conditions (Emeran et al. 2011). The use of many genetic methods based on developing various disease-resistant cultivars to *U. viciae-fabae* is an additional approach to control this rust disease (Cooper & Campbell 2017, Ijaz et al. 2021).

Conclusion

The rust fungi are an important component in the field of plant pathology. Studying these fungi on various aspects has made much progress during the present century. These fungi provide an important platform for researchers to study their autoecious and heteroecious nature and help of macrocyclic and microcyclic mode of life cycle. The information compiled here revealed that *Uromyces viciae-fabae* is an autoecious and macrocyclic rust fungus which showed global distribution. This article hopefully generate curiosity among scientists to join research on rust fungi. However, study based on molecular characterization of this most interesting pathogen are not well studied which reflects the future research possibilities. Moreover, research on biological control of this fungal pathogens also required much attention. Overall, this compilation may be proved useful to plant pathologists particularly urediniologist of the world.

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