# EPIDEMIOLOGY AND MANAGEMENT OF FIG RUST CAUSED BY *Cerotelium fici* (Cast.) Arth.

**ANUSHA A.**

**DEPARTMENT OF PLANT PATHOLOGY**
**COLLEGE OF HORTICULTURE, BAGALKOT**
**UNIVERSITY OF HORTICULTURAL SCIENCES,**
**BAGALKOT, KARNATAKA, INDIA**

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# EPIDEMIOLOGY AND MANAGEMENT OF FIG RUST CAUSED BY *Cerotelium fici* (Cast.) Arth.

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**By**

**ANUSHA A.**
ID No. UHS16PGM767

**DEPARTMENT OF PLANT PATHOLOGY**
**COLLEGE OF HORTICULTURE, BAGALKOT - 587 104**
**UNIVERSITY OF HORTICULTURAL SCIENCES,**
**BAGALKOT - 587 104**

**2018**

# UNIVERSITY OF HORTICULTURAL SCIENCES, COLLEGE OF HORTICULTURE, BAGALKOT DEPARTMENT OF PLANT PATHOLOGY

## CERTIFICATE

This is to certify that the thesis entitled **"EPIDEMIOLOGY AND MANAGEMENT OF FIG RUST CAUSED BY *Cerotelium Fici* (Cast.) Arth"** submitted by **MISS. ANUSHA A., ID. No. UHS16PGM767** for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **PLANT PATHOLOGY** of the University of Horticultural Sciences, Bagalkot is a record of research work done by her during the period of her study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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**Date : 20-09-2018** Chairman

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***Chairman*** **1. _____**
**(MAHESH Y. S.)**

***Members:***

**2. _____**
**(R. K. MESTA)**

**3. _____**
**(BASAVARAJAPPA M. P.)**

**4. _____**
**(S. N. PATIL)**

**5. _____**
**(BABU A. G.)**

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Dedicated to
My Ever loving Father

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# 1. INTRODUCTION

Fig (*Ficus carica* L.) is an important deciduous fruit crop of tropical and subtropical countries. It belongs to the family, *Moraceae*, which consists of about 40 genera and 1400 species of trees and shrubs (Watson and Dalwitz, 2004). It is the species known around the world for its edible fig and has been cultivated for thousands of years, with traces of found in excavations of Neolithic sites traced to at least 5,000 BC (Morton, 1987).

Edible fig is a deciduous tree grows up to 5 to 8 m tall with rounded or broadly ovoid crown, sometimes shrubby and branching from base. The bark is grey, more or less smooth. Buds are glabrous. The leaves are alternate, thick and palmate, with 3 to 7 deep dissections, each coarsely toothed. Leaves are up to 25 cm (10 long), with a scabrous (rough) upper surface and pubescent (soft hairy) underneath. The synconium (fruiting structure) that grows in the axils (where leaf meets stem) may range in colour from yellow to green to purple to bronze on the outside with 30 to 1600 tiny flowers inside.

The pollination of fig is very special and reflects symbiotic relationships. It is carried out by a parasitic species-specific wasp (*Blastophaga psenes)* whose life-cycle is synchronized with that of the tree.

The latin name, *carica* is named for the location Caria in Asia Minor which is supposedly the home of the fig (Starr *et al.,* 2003). Transcaucasia is considered as one of the centres of origin and diversity by Vavilov, as one could see all phases of the domestication of fig in the southern Caucasus, where wild, transition and modern fruit growing still exists (Aradhya *et al.,* 2010).

The fig tree is mentioned several times in the Bible under the name tannana (Strawberry tree) and is included in the garden of Eden. Arabs esteemed figs above all other fruits. Zamakkhschari, an Arabian interpreter of the Koran, reported that Mohammed said, "If I could wish a fruit brought to paradise it would certainly be the fig" (Anon., 2018)

Though the preferred common name is common fig, it is also called by other names *viz.*, higo (Spanish), caprifiguier (French), teen (Arabic), wu hua guo

(Chinese), figueira (Portuguese), figueira da Europa (Brazil), monamona (Cook Islands), higo extranjero (Dominican Republic), viikuna (Finland), Echter Feigenbaum (Germany), figuier blanc (Haiti), anjir (India), fico (Italy), te biku (Kiribati), muhwagwanamu (Korea), thinbaw-thapan (Myanmar), Vijgeboom (Netherlands), uosech (Palau), Bebereira (Portugal), Mati (Samoa), Fikontraed (Sweden) and fiki (Tonga) and several other local names.

The edible fig and their pollinating counterpart, caprifigs, are the only members of the subgenus *Eusyce* grown commercially for their fruit. Four types of figs are described based on cropping and pollination characteristics. The type known as common fig requires no pollination to set a commercial crop. These types are referred to as "persistent" rather than parthenocarpic since the fig is not a true fruit. The chromosomes of the various fig species are similar to each other in appearance and 2n = 26 is the basic chromosome number in all figs. Several allied members of this subgenus closely resemble true *Ficus* species and members intermediate in form between true *Ficus* and these allied species suggest hybridization among them.

Figs are highly nutritious rich in calories. The protein and calcium content in fig fruit is higher than that of the milk. It has nutritive index of 11, as against 9, 8 and 6 for apple, raisin and date respectively. The total sugar content of the fresh fig is around 16 per cent and dried is 52 per cent. The edible portion of dried fig (100 g) supplies protein (4 g), carbohydrate (69 g), fat (1 g), calcium (200 mg), iron (4 mg), vitamin A (100 IU) and thiamine (0.1 mg). They are used in numerous dessert, baked goods, jams, preserves, as well as in some savory and meat dishes. Fig cakes were eaten since ancient times. The fruit helps to maintain acidic-alkali balance of body. They have been used in folk-medicine. The milky sap, though irritating, has medicinal properties. Latex is useful to coagulate milk. Fig is valued for its laxative properties and is used in the treatment of skin infection. Pliny of Rome (62-113) said "Figs are restorative, the best food that can be eaten by those who are brought low by long sickness and are on the way to recovery".

Therefore, the fig has secured a significant place in the world due to its nutritional importance and there are many value added products like dry fig, fig fruit leather, jam, sweet meat, cake and powder which are increasing the demand for fig fruits both in local and world market.

The total land brought under the cultivation of fig in the world is 4.15 lakh ha. Turkey is the leading fig producing country in the world, followed by Egypt and Algeria. Other major fig growing regions of the world are Portugal, Iran, spain, Turkistan, Tayunishia, Syrian, Albania, USA, India and Pakistan.

In India, total area under fig cultivation is 13,802 ha with the production of 24,646 tons, mostly with an average productivity of 2,516 kg/ha during the year 2014-15 (FAO, 2017). India ranks fifteenth in fig production in the world. However in case of productivity, India ranks twenty second. Its cultivation is mostly confined to western part of Maharashtra, Gujarat, Uttar Pradesh (Lucknow and Saharanpur), Karnataka (Bellary, Chitradurga and Koppal) and Tamil Nadu (Chadha, 2001). Among these states, Maharashtra is leading in fig cultivation with an estimated area of about 2,242 ha, with an annual production of 7,894 metric tons and productivity of 3.52 tons/ ha/ year. In Maharashtra fig is grown in Pune, Ahmednagar and Aurangabad districts. Karnataka stands next to Maharashtra in fig cultivation holding an area of about 641 ha, producing an average of 6,021 metric tons of fig fruits annually with the highest productivity of 9.39 tons/ ha/ year (Anon., 2017).

*F. carica* can tolerate a range of habitats. It was originally adapted to semi-arid subtropical regions; however, it can be found both in the natural flora in mild temperate climates and in the tropics as an evergreen. It can be grown on all types of soils, preferably on sandy-clay loam within a pH range of 6.0-8.0. It is known to tolerate higher lime contents, but highly acid soils are unsuitable. A soil depth of 1-1.5 m provides the required growth conditions. A frost of -5 to -10 ˚C may kill the plant down to ground level. It is tolerant to drought but irrigation enhances the growth and yield of the crop. The tree is fairly tolerant of moderate salinity (Morton, 1987). It can tolerate a fairly high level of sulphate or chloride salt. Soils having high lime content can produce fruits of better quality suitable for drying.

With the increasing demand and production there are many constraints limiting the fig productivity, which includes both biotic and abiotic factors. Like the other crops it is affected by many destructive pest and diseases. This crop has reported many diseases caused by fungi, bacteria and viruses. The most important diseases observed on fig are rust (*Cerotelium fici*), anthracnose (*Colletotrichum gloeosporioides*), *Armillaria* rot (*Armillaria mellea*), bacterial canker (*Pseudomonas*

*fici*), leaf spots (*Cylindrocladium scoparium* and *Cercospora fici*), aerial web blight (*Rhizoctonia solani*), sooty mold (*Capnodium* spp.), pink limb blight (*Corticium salmonicolor*), nectriella stem gall (*Kutilakesa pironii*), fruit rot (*Phytophthora palmivora* and *Ceratocystis fimbriata*), *Rosellinia* root rot (*Rosellinia necatrix*), smut (*Aspergillus* spp.), canker (*Phomopsis cinerascens*), crown gall, leaf blotch, stem canker and fig mosaic (Fig mosaic virus).

The rust caused by *Cerotelium fici* (Cast.) Arth. is the most important fungal disease and was reported in India for the first time in 1914 (Butler, 1914). The *Cerotelium* is earlier referred as *Physopella* which is a telomorph of the *Cerotelium*. The phylogenetic relationship of the genus says that it is closely related to the *Phakopsora* genus parasitizing the leguminous crops (Ono *et al.*, 1992). It is found to infect other species of the *Ficus* genera also.

The disease symptoms develops initially as tiny yellow spots on underside of the leaves. They enlarge to form reddish brown angular spots visible on lower and upper leaf surfaces. Leaves are the severely affected plant part by rust disease. However, under congenial condition, symptoms also appear on petiole, shoots and fruits. Severe disease incidence results in leaf drying and defoliation. Defoliation is accelerated because the fungus is polycyclic and new full sporulation is completed every 20-30 days (Pastore *et al.,* 2017). About 50 per cent losses have been reported by earlier workers (Gaikwad and Nimbalkar, 2004) indicating the seriousness of rust disease in fig. Fig rust is favoured by warm and humid weather during vegetation period.

At present, the rust disease has become a major limiting factor in fig cultivation. The rust is an endemic disease and severe in all parts of the state where the crop is grown. The fig growers income is affected by this disease as it is causing considerable damage to the crop. So, the effective management strategies for the rust disease are crucial. The control of plant disease can be attempted by a range of strategic methods which includes scheduling of the cultural operations like pruning, host resistance, nutrient management and applications of chemicals. Though there are many fungicides with their proven efficacy against the pathogen, there residues over the fruits have become one of the constraint in marketing as it is found to have health risk.

Therefore, looking in to the economic importance of the disease and need of the farmers, it was felt to initiate systematic studies on the management of rust disease. Consequently, now the present studies are directed to throw some lights on several aspects like search for fig rust incidence, estimation of biochemical parameters in the leaves to understand the host metabolic changes with the advancement of the infection and for managing the disease, identification of resistant variety, evaluation of fungicides, botanicals and bioagents. Hence, the present investigation was undertaken with the following objectives:

**Objectives:**

1. Survey for fig rust severity in major fig growing regions of North Karnataka.
2. Effect of sugars, temperature and relative humidity on uredospore germination of *Cerotelium fici*.
3. Screening of fig varieties for resistance to rust disease.
4. Management of fig rust using chemicals, biorationals and bio agents.

# 2. REVIEW OF LITERATURE

The fig (*Ficus carica* L.) plant and other species of the family Moraceae is threatened by the rust disease caused by *Cerotelium fici* (Cast.) Arth. The fungus is predominantly distributed in all the fig growing regions and is found to affect the productivity of the crop describing its economic importance. Though the fungus was described early in the 20$^{th}$ century, the appropriate work about fungus and other aspects with regard to the fig plant is modest. Consequently the review of literature presented here is also composed of other appropriate systematic narratives.

## 2.1 Symptomatology

Mckenzie (1986) reported that fig rust *(Cerotelium fici* (E. J. Butler) Arthur), is causing the premature leaf fall of fig trees in Auckland of Newzealand in early Febraury, 1986.

Uredinia of *Cerotelium fici* mainly hypophyllous and on fruit, scattered and sometimes on leaf tends to be grouped around edge or in dew drop runs on lamina, pale reddish-brown, often on reddish-brown angular leaf spots (corresponding brown spots on upper surface coalescing and becoming necrotic), pulverulent, circular, up to 0.5 mm diameter. Urediniospores are (19.5 -) 24 - 30 (- 35) x (14 -) 16 - 20 (-22) µm in size, globose, obovoid, ellipsoidal or angular in shape, having a wall of 0.5 -1 µm thick, pale and sparsely echinulated. Germ pores are obscure (3 - 4) and equatorial on the uredospores (Mckenzie, 1986).

The etiology and epidemiology of leaf rust of mulberry plant (*Morus alba*) was investigated at Ibadan, South-western Nigeria in the lowland humid tropics. The *Cerotelium fici* was found associated with leaf blight and seedlings blight of mulberry. Field symptoms of the disease were common in the dry and wet season beginning with numerous pin-head sized circular brownish to black eruptive lesions on the surface of the leaves. Affected leaves turned yellowish and withered as the disease became severe. Matured leaves were reported to be more susceptible to the disease (Baiyewu *et al.*, 2005).

Saba *et al.* (2013) during their survey in the Azad Jammu, Kashmir and adjacent northern areas of Pakistan identified eleven different host plants infected

with ten rust fungi belonging to five different genera. Those are *Cerotelium fici*, *Puccinia aestivalis*, *P. chrysanthemi*, *P. sibirica*, *P. swertiae*, *Pucciniastrum agrimoniae* and *Transzschelia discolor* in Azad Jammu and Kashmir regions whereas *Puccinia nitidula*, *P. siberica* and *Uromyces vossiae* found in the northern areas of Pakistan.

An important disease on the fig plants in the nurseries of Montenegro in the 2014 was reported by Latinovic *et al.* (2015). The leaves of diseased trees were found twisted upwards with rusty and necrotic areas and then dried. Numerous yellow to brown coloured spots on the upper side and reddish-brown pustules on the lower side of the leaves were noticed. Bare branches and unripe fruits were noticed due to the premature leaf fall. Microscopic observations in laboratory revealed that the disease is caused by the phytopathogenic fungus *Cerotelium fici* which was favoured by humid and warm summer weather.

A survey of plants in Panchgaon revealed the infection of *Cerotelium fici* on the *Ficus benjamina* L. Symptoms were recorded as small, yellow to yellow green spots on leaves as tiny, raised, bright rust pustules on the adaxial surface of the leaf. The spots enlarged and developed brownish tinge. The uridinospores formed from the extending mycelium emerged through ruptured epidermis. Symptoms were absent on the stem and apical buds (Kumar and Khurana, 2015).

The hyphophyllous uredinia of *Cerotelium fici* on *Ficus benjamina* was observed to be surrounded by numerous incurved paraphyses. The spermagonia, aecia and telia were not seen (Kumar and Khurana, 2015).

Pathak *et al.* (2016) reported the incidence of rust caused by *Cerotelim fici* on seedlings of *Ficus benghalensis* L. *F. religiosa* L. and *F. racemosa* L. maintained in the nursery seedling beds of Forest Research and Extension Circle, Indore, India.

## 2.2 Survey for fig rust severity

*C. fici* causing fig rust is widely distributed in the tropical and subtropical regions where fig is cultivated (Thirumalachar *et al.,* 1950). A survey conducted in mulberry orchards indicated that the leaf rust was caused by *C. fici* was more serious (Sastry, 1984).

Gunasekhar *et al.* (1995) conducted a survey in selected mulberry growing areas under different agro climatic zones located in Andhra Pradesh, Karnataka, Kerala and Tamil Nadu during 1990-1992 and found high incidence of leaf rust (*C. fici*) during winter followed by rainy season. Another survey conducted in Ludhiana revealed the pathogen *C. fici* causing leaf rust of fig (Verma and Kapur, 1995).

Phillip *et al.* (1997) studied the incidence of foliar and soil borne diseases of mulberry such as leaf rust, powdery mildew, leaf blight and root knot in Madanpalle and Chittoor of Andhra Pradesh, Hosur of Tamil Nadu and Malavalli and Chamarajanagar of Karnataka state during the rainy season of 1994. They observed that among several diseases, rust caused by *C. fici* was more prevalent in all the places surveyed.

Gupta *et al.* (2013) conducted a survey of the randomly selected wheat fields in sub-tropical to temperate agro-ecologies of Jammu province of Jammu and Kashmir consecutively for three years 2009-2010, 2010-2011 and 2011-2012 during rabi, to assess the prevalence and distribution of wheat stripe rust (*Puccinia striiformis*). The results revealed that, by and large, all the wheat growing areas under study were found infected by this disease. The cropping season of rabi 2010-2011 recorded highest disease prevalence which was stated due to conducive environmental conditions coupled with virulent pathotypes out-break and monoculture of wheat varieties.

Pannu *et al.* (2014) conducted surveys for the prevalence of yellow or stripe rust (*Puccinia. striiformis* f. sp. *tritici*) of wheat in which they reported that the disease, yellow or stripe rust wheat first appeared at certain locations in the sub-mountainous districts of SBS Nagar, Ropar, Hoshiarpur in the Punjab State and adjoining areas of Himachal Pradesh from where it spread further to other areas. Severity of yellow rust in different districts of Punjab varied from 6.5-35.6, 2.6-28.5 and 3.5-20.5 per cent during 2010-11, 2011-12 and 2012-13 respectively.

Chandrakant *et al.* (2015) conducted a survey on foliage diseases of the primary host plant *Persea bombycina* Kost. of Muga silkworm during the calendar year 2012 and 2013. They recorded that the foliar diseases like red rust, leaf spot, grey blight and brown blight are common diseases occurring on the plant species in the

Bageshwar district of Uttarakhand state, which affects the foliage yield of the plant as well as quality and quantity of cocoon production.

Sharada and Jahagirdar (2015) carried out a survey on severity of soybean rust at farmers field in different villages of Dharwad, Bidar, Belagavi, Haveri and Bagalkot districts of Northern Karnataka during Kharif, 2013. The results revealed that the disease exists in all the regions in low to severe form with PDI ranging from 25.55 to 94.66 during kharif, 2013. The Bagalkot district recorded the maximum rust severity (57.77), whereas the Haveri district recorded the mininmum disease severity (38.88).

Upadhyay *et al.* (2015) during their survey in the localities of Uttarakhand and Uttar Pradesh for the prevalence of pea rust during 2013-2014 and 2014-2015 reported that the disease incidence and per cent disease severity was ranged from 37.50 to 90.00 and 1.28 to7.37. Disease incidence was highest in Rampur district of Uttar Pradesh, whereas maximum disease severity was observed in Udham Singh Nagar district of Uttarakhand.

### 2.3 Proving Pathogenicity

Different methods of inoculation with uredospores of *C. fici* were evaluated to find out most effective method for production of maximum disease in order to obtain fresh mass of uredospores for using in different pathological studies. The study revealed that all the methods of inoculation were effective in inducing the rust severity to more than 50 per cent. However, among the seven methods of inoculation, leaf dip, micro droplet and hand inoculations were found most effective overall other methods wherein, significantly maximum (73.33 %) rust severity was observed with latent period of seven days. The next method in order of superiority was spore dusting inoculation (66.67 %) which is on par with above mentioned three methods and has a latent period of 7 days. It was followed by stapler method of inoculation, where the latent period was seven days with PDI of 60 per cent. Among all the methods, cotton swabbing showed more latent period (9 days) with least PDI of 53.33 per cent (Ramanath, 2013).

The Kentuky blue grass (KBG) cultivars were inoculated separately with one isolate of each rust species *viz.*, *Puccinia graminis* (stem rust) and *Puccinia coronata*

(crown rust). The inoculum consisted of 0.10 g of urediniospores suspended in 1 ml of light mineral oil per plant. The mineral oil or spore suspension was sprayed onto the foliage of 5 week post emergent KBG plants in a fume hood. In the controlled conditions uredospores developed on inoculated plants 10 to 14 of days post inoculation. Real-time polymerase chain reaction (PCR) assays, disease symptomology and morphology of uredospores confirmed the presence and identity of both rust pathogens from inoculated host tissue (Beirrn *et al.*, 2015).

From 60 telia of *Puccinia striiformis* f. sp. *tritici*, mature teliospores from a single wheat plant were suspended in 1.0 ml of distilled water and inoculated with a fine paint brush onto the leaves of seven or eight 10- to 15-day-old plants of *Mahonia aquifolium* (Oregon grape) an alternate host for the wheat stripe rust pathogen. Plants were incubated initially in a dew chamber at 10˚ C for 72 h in darkness, then transferred to a growth chamber with a diurnal temperature cycle of 10 to 24˚ C and a 16 h light or 8 h dark cycle. Reddish pycnia with nectar appeared on adaxial surfaces of inoculated leaves at 12 days post-inoculation (DPI) and reddish aecia were produced on the abaxial surface at 16 DPI. All 15 *M. aquifolium* leaves of the 15 plants inoculated with teliospores produced pycnia and aecia. Seedlings of Nugaines and Avocet S, wheat cultivars that are susceptible to all *Pst* races, were then inoculated with a water suspension of aeciospores of 30 aecia collected from the *M. aquifolium* plants. Wheat plants were incubated as described above for *M. aquifolium*. Uredinia appeared at 15 DPI and telia were produced after an additional 15 days (Wang and Chen, 2013).

The typical *Cerotelium fici* symptoms were observed after 15 days on spray inoculated leaves of *Ficus benjamina*. The spray suspension was prepared by dissolving one 5 mm diameter of rust pustule in 100 ml double distilled water. The uredospore developed after 25 days of inoculation (Kumar and Khurana, 2015).

## 2.4 Effect of sugars, relative humidity and temperature on uredospore germination

The uredospore germination of *Melampsoridium betulinum* was reported to be optimum at 10˚ C and uredospores were germinated from 10-20˚ C. Uredospores were killed when exposed to 30˚ C for six h and at 35˚ C for 30 min. On the detached leaf

the uredia development was observed at 10-20˚ C and 100% relative humidity. The development of uredia is observed within 13-14 days at 12˚ C on attached and detached leaf (Doodley, 1984).

Germination of uredospores of *Puccinia substriata* var. *indica* causing pearl millet rust was evaluated after 2, 4, 6 and 8 h of incubation in petri dishes containing 2% water agar under 10, 16, 20, 25, 30 and 35˚ C in light (1650 lux, cool white fluorescent), dark, alternate light-dark and alternate dark-light. Less than 1% germination was observed at 35˚ C. At 30˚ C, per cent germination did not showed any significant change after 4 h of incubation. At 10˚ C, per cent germination increased with longer incubation. Under all illumination conditions, maximum per cent germination occurred at 20–25˚ C after 4 to 8 h. Response surface analysis indicated that under all four illumination regimes, uredospore germination greater than 90 per cent occurs between 19 and 22˚ C after 6–7 h of incubation. Two hours of continuous light appeared to significantly delay germination, but exposure to light during the first hour of incubation was stimulatory when followed by 1 h dark (Tapsoba and Wilson, 1997)

Sumangala *et al.* (2014) revealed that uredospores germinate at temperature range of 5.0˚ C to 35˚ C. The maximum (87.37%) spore germination of *Puccinia melanocephala* was observed at 25˚ C after 24 h of incubation and at 85 per cent RH. Uredospore germination was least (38.6%) at 65% RH. The maximum uredospore germination of 75.30 per cent was recorded in two per cent sucrose solution. Among the sugar solutions, least uredospore germination (50.45%) was observed with dextrose at 0.5 per cent.

*In vitro* experiments were conducted to assess the effects of substrate, temperature and time of exposure to temperature and photoperiod on *Phakopsora pachyrhizi* (soybean rust) uredospore germination and germ tube growth. The water-agar and soybean leaf extract-agar at different leaf concentrations (0.5, 1.0, 2.0 and 4.0 g of leaves and 15 g agar/L water) were tested as substrates. The highest germination and germ tube length was found in the soybean leaf extract agar. Maximum *P. pachyrhizi* uredospore germination was obtained at 21.8 and 22.3˚ C and maximum germ tube growth at 21.4 and 22.1˚ C. The maximum uredospore germination was found at 6.4 hours of exposure, while the maximum germ tube

length was obtained at 7.7 h exposure. Regarding photoperiod, the maximum spore germination and the maximum uredospore germ tube length were found in the dark. Neither spore germination nor uredospore germ tube growth was completely inhibited by the exposure to continuous light (Blum *et al.,* 2015).

Veena and Adiver (2015) conducted *in vitro* studies on effect of temperature and relative humidity on uredospore germination of *Puccinia arachidis.* They revealed that maximum spore germination was occurred at 25˚ C in 24 h in all the isolates of fungus. The isolates, *PaMAN* showed maximum spore germination (90.00%) and *PaHIR* showed minimum germination (65.00%) in 25˚ C. The maximum spore germination was observed at 90 per cent RH in all the isolates and the isolates *PaHUB* showed maximum spore germination (93.00%) and minimum (82.67%) was recorded in *PaMOR*.

Dey *et al.* (2015) determined the temperature effects on uredospore germination of *Puccinia sorghi* (sorghum rust). Spore germination was maximum within 24 h of incubation, in the temperature range of 20-30˚ C. The mean maximum spore germination was recorded at 25˚ C (66.16%) which is statistically on par at 30˚ C (optimum range). The germination per cent declined gradually at temperatures above and below 25 °C. The maximum reduction in germination was recorded at 30 °C and 2 h time interval. Thus, the cardinal temperatures for uredospore germination on water agar were 5, 25 and 35˚ C for 24 h of incubation, respectively. At the maximum and minimum temperature levels, the minimum incubation period extended beyond two hours.

### 2.5.1 Screening of fig varieties for resistance to rust disease

The studies of Prakashan and Thamburaj (1991) revealed that among 15 accessions of fig screened in the field at Yercaud, Tamil Nadu only Timla fig (*F. auriculata*) remained free from rust infection.

Reddy *et al.* (1997) screened six promising fig cultivars *viz.,* Poona fig, Black Ischia, Doulatabad, Maisram, Shahi and Hindupur for their reaction to *C. fici* at Anantapur, Andhra Pradesh. All were rated susceptible, although Black Ischia and Doulatabad had significantly lower disease incidence.

Screening trial was conducted for identification of resistant varieties/lines against soybean rust caused by *Phakopsora pachyrhizi* under natural epiphytotic conditions at Barapani, Meghalaya, India. Twenty three lines varieties/lines were included in the trial along with a susceptible check JS 335. Results revealed that only two lines NRC 80 and MAUS 417 were moderately susceptible. Lines TS 5, Himso 1676 and MAUS 282 were highly susceptible and all other lines were susceptible. No line or variety was in the moderately resistant or resistant category as all the lines exhibited Tan type lesions (Baiswar *et al.*, 2012).

Twenty one germplasms of wheat *viz.*, PBW-343, PBW-550, Raj- 3765, Raj-3077, PBW-502, PBW-373, PBW-396, VL-804, TL-2966, HPW-289, VL-916, HS-508, TL-2942, TL-2963, HS-240, VL-907, HS-507, Agra Local, TBW-17, V-21 and RSP-561 were screened under artificial epiphytotic conditions for stripe rust (*Puccinia striiformis*) resistance at Research Farm, SKUAST-J, Chatha of Jammu and Kashmir during cropping season of *rabi*, 2009 to 2010. Among twenty one germplasms screened, Agra local and PBW-343 were found susceptible, RSP-561 showed moderate resistance, whereas all the other cultivars were moderately susceptible (Gupta *et al.*, 2013).

A study was conducted to evaluate *Puccinia striiformis* f. sp. *tritici* (*Pst*) resistance and its effective genes in wheat genotypes. For this, trap nurseries, wheat stripe rust differentials, commercial cultivars and advanced breeding lines were tested under artificial epiphytotic and natural hot spots conditions during 2005 to 2010. Four genes (*Yr*5, *Yr10*, *Yr15* and *YrSp*) consistently showed resistance to the prevailing races. The gene *Yr*9 and *Yr27* in combinations with *Yr*18 were found effective. Other lines with combination of minor genes were also found effective. The genotypes Amadina, Kukuna, Tukuru, Kakatsi and Buck Buck widely used in breeding program were resistant (Sharma *et al.*, 2015).

Chapola *et al.* (2016) conducted a study to determine the reaction of Brazilian sugarcane varieties to the orange rust disease (*Puccinia kuehnii*) in the field of Araras, Sao Paulo state, Brazil. Rust severity was assessed in 17 varieties at 15-day interval. The maximum disease severity (MS%) and the Area under disease progress curve (AUDPC) were determined for each genotype. They found that nine out of the 17 varieties screened were resistant to the disease. Varieties RB72454, SP89-1115 and

SP79-2233 were susceptible, while RB925211 and SP81-3250 were moderately susceptible. Varieties RB855156, RB92579 and SP83-2847 showed an intermediate reaction.

Pastore *et al.* (2017) evaluated 34 fig landraces accessed from urban and rural areas of the state of Santa Catarina, Brazil and cv. Roxo de Valinhos against rust (*Cerotelium fici*) during 2013- 14. Biweekly assessments of incidence and severity revealed that the genotypes of thick, purple fruits from Lages and Western Santa Catarina and the genotypes of thin, purple fruits from Lages and from Western Santa Catarina were found to be highly resistant to the rust disease. Roxo de Valinhos, a commercial cultivar of Brazil was found to be highly susceptible.

### 2.5.2 Area under disease progress curve (AUDPC) and apparent rate of infection (r)

Sreekantappa and Naik (2004) considered two varieties of fig for slow rusting property as resistance to the rust disease caused by *Cerotelium fici* for which they recorded AUDPC values, latent period, uredia per square centimeter, size of the uredium and uredospore per uredium. Both Poona and Bellary varieties showed a latent period of 8-9 days. The uredia per square centimeter ranged from 4.4-4.7 and 4.3-4.5 in Poona and Bellary varieties, respectively. The size of uredium of Poona was recorded as 0.155 - 0.224 $mm^2$ whereas that of Bellary 0.178-0.215 $mm^2$. The uredospores per uredium in case of both Bellary and Poona varieties ranged from 1500-2000 whereas the size of uredospore ranged from 1-1.1 x 1.1µm in both the varieties without any variation. The AUDPC values were 9116.0 for Poona and 8815.9 for Bellary varieties and none of them were found to be slow rusters.

Chand *et al.* (2006) used the AUDPC values for screening of 345-germplasm lines of *Pisum sativum* to rust disease caused by *Uromyces fabae* as resistant (slow rusting) or susceptible (fast rusting). The resistant genotypes recorded lower AUDPC values compared to the susceptible genotypes.

For assessing the partial resistance among the genotypes, the parameters like final rust severity (FRS), area under rust progress curve (AURPC), infection rate (IR) and co-efficient of infection (CI) were suggested as useful parameters in a study conducted by Ali *et al.* (2008) while screening wheat germplasm for resistance to stripe rust disease.

Gupta *et al.* (2013) in a survey on wheat stripe rust reported the maximum and minimum Area Under Rust Progress Curve (AURPC) values of 2422.21 and 351.70 from Jammu sub-tropics and inter-mediate Doda districts, respectively.

The Som genotype M-8 recorded the 3.6 fold and 4.2 fold higher Disease incidence and severity index (DSI) and area under disease progress curve (AUDPC) values respectively, compared to the partially resistant genotype M-5 to the *Phyllactinia* leaf spot (PLS), caused by *Phyllosticta persae* (Chattopadyay *et al.*, 2014).

The wheat genotypes having partial adult plant resistance to leaf rust caused by *Puccinia triticina* recorded AUDPC less than 332.5 and apparent rate of infection (r-value) less than 0.101 (Draz *et al.*, 2015).

Hanamanth *et al.* (2015) suggested that the AUDPC values as more reliable than r -values (apparent rate of infection) for measuring the slow rusting principle of the pearl millet genotypes.

### 2.5.3 Environmental factors and rust development

Rust epidemics on rose apple in central Brazil were shown to depend on the duration of leaf wetness in the dark and also on night-time temperature with same wetness period (Tessmann *et al.*, 2001).

Ponte *et al.* (2006) in a study conducted on soybean rust reported that temperature variables had lower correlation with disease severity compared with rainfall and had minimal predictive value for final disease severity.

Correlation and regression studies on leaf rust of mulberry indicated that weather factors such as maximum and minimum temperature, per cent relative humidity, cumulative rainfall and total rainy days and crop age were significantly and positively correlated with disease initiation and its development (Srikantaswamy *et al.*, 2006).

Beest *et al.* (2008) suggested that the temperature in February to June was the most influential factor for a damaging epidemic and disease severity for the yellow rust of wheat.

Maximum daily temperature was the variable most correlated with seasonal epidemic development and decline of brown rust in sugarcane, caused by *Puccinia melanocephala*. An accumulation of 23–25 days with leaf wetness periods of at least 7 h after the daily minimum temperature exceeded 17˚ C preceded the onset of disease on young leaves in both severe and mild epidemics (Barerra *et al.*, 2013).

Kanade *et al.* (2015) conducted an experiment on the rust disease incidence and severity in groundnut crop at different sowing dates. The observations on initiation of rust disease and per cent disease intensity were recorded periodically at an interval of one week after the occurrence of the disease. Maximum temperature (0.59), morning relative humidity (0.33), evaporation (0.33) and bright sunshine hours (0.55) showed positive correlation with disease intensity. Whereas, minimum temperature (-0.44), evening relative humidity (-0.58) and wind speed (-0.63), showed negatively significant correlation with disease intensity in *Kharif* season. Other climatic factors *i.e.,* rainfall showed no significant correlation with disease intensity. The morning relative humidity and bright sunshine hours were correlated for rust disease incidence. The result from all the relevant observations indicated that the morning relative humidity (2.87) and bright sunshine hours (5.65) during the crop growing period was found to be highly significant weather conditions for rust disease development. The multiple regression equation developed from the data in this regard is as: Y= -257.591 +2.879RH-I (W-1) +5.651BSS (W-1).

Sandhu *et al.* (2017) analysed the weather parameters on stripe rust of wheat caused by *Puccinia striiformis* f.sp. *tritici* during 2012-13 and 2013-14 and reported that temperature and relative humidity were the most important weather parameters which effected disease incidence and severity maximum and could be used as key indicators in stripe rust forewarning under Punjab conditions.

The correlation between different meteorological parameters and rust severity in pea crop revealed that per cent disease severity was highly positively correlated with maximum temperature (r = 0.977), minimum temperature (r = 0.704), rainfall (r = 0.039) and wind velocity (r = 0.093) whereas negatively correlated with morning (r=-0.925) and afternoon RH (r = -0.926) (Upadhyay *et al.*, 2017).

### 2.5.4 Study of biochemical parameters in relation to the disease resistance

Epicuticular wax deposition on sorghum (*Sorghum bicolor* L. Moench) leaf blades imparts drought resistance. Screening of a large number of sorghum genotypes for increased leaf epicuticular wax content was conducted by Ebercon *et al.* (1977) by developing a rapid colorimetric method and evaluated against gravimetric method. The colorimetric method is based on the colour change produced due to the reaction of wax with acidic $K_2Cr_2O_7$ reagent. Wax content determined by the colorimetric method was highly correlated (r = 0.984) with that determined by the gravimetric method. Leaf epicuticular wax content in 11 fieldgrown grain sorghum cultivars did not vary between growth stage #4 (tip of flag leaf showing) and #7 (soft dough), at which stages comparable wax readings were obtained among the four top leaf blades. A CK 60 'bloom less' (bmbm) genotype had only half of the epicuticular wax content of the CK 60 'normal' (BmBm) genotype. Ten cultivars, all of the BmBm genotype, significantly differed in epiculticular wax content, ranging from 1.14 to 1.99 (SE = 0.006) mg/dm$^2$ of leaf.

The concentration of the phenolic compounds increase due to infection more particularly of chlorogenic and *trans* and *cis* caffeic acids in rust infected ground nut leaves (Reddy, 1984).

Sunkad and Kulkarni (2006) studied the mechanism of resistance on the basis of structural and biochemical changes in resistant (GPBD- 4 and DH-22), moderately resistant (K-134 and R-8808) and susceptible (KRG-1 and TMV-2) genotypes of groundnut. They found that resistant and moderately resistant genotypes were characterized by higher cuticular and epidermal cell thickness with lesser epidermal cells, size (length, breadth) and number of stomata and more wax content at later stages of crop growth. Resistant and moderately resistant genotypes recorded more sugars, phenol, ortho-dihydroxy phenol and protein contents than susceptible ones.

Ammajamma and Patil (2008) evaluated biochemical parameters of soyabean genotypes at 45 and 75 days after sowing (DAS) to study their involvement in the resistance to the rust disease caused by *Phakopsora pachyrhizi*. The study revealed that the resistant genotypes had more (21.25 and 32.19% at 45 and 75 DAS, respectively) of total phenols than susceptible genotypes. Total sugar content was 1.5

and 14.42 per cent more in resistant genotypes compared to susceptible genotypes at 45 and 75 DAS, respectively. Similarly, total chlorophyll content in resistant genotypes at 45 DAS was 10.75 per cent more than susceptible genotypes. At 75 DAS, 15.33 per cent more of total chlorophyll was recorded in resistant genotypes compared to susceptible genotypes

Arun *et al.* (2010) showed that the total phenols increased in the infected resistant host plant upon infection by *Sclerospora graminicola* in the pearl millet plants. Total amino acids and free proline contents were also increased manifold (1222.2 and 942.6%, respectively) in diseased tissues, particularly in resistant cv. HHB 67 than in susceptible one (Eknath).

The phenolic content in all cultivars of maize increased after the *Rhizoctonia solani* f. sp. *sasakii* infection causing banded leaf and sheath blight. This increase was more pronounced in resistant cultivars as compared to susceptible cultivars. Further analysis of the data revealed that the disease severity was negatively correlated with the accumulation of phenol having coefficient of correlation r = -0.83 (Akhtar *et al.,* 2011).

Hau *et al.* (2014) determined the soluble sugar and total phenol contents in the leaves of 29 pear cultivars with varying levels of resistance to scab caused by *Venturia nashicola* in May, June, August and September, 2012 in China. Their study revealed that the changes in soluble sugar and total phenol contents in the leaves of interspecific pears appeared to be relatively stable in May, June and August. Significant changes in their levels were observed in September month. Total phenol content in pear cultivars which were immune to scab was slightly higher than the resistant cultivars in May, June, August and September. However, their study did not showed any significant correlation between total sugars, phenols and scab incidence in the resistant cultivars.

Healthy and infected stem and leaves of the *Jasminun officinale* var. *grandiflorum* infected by *Uromyces hobsoni* were collected directly from the field and were analyzed for the activity of defence enzymes like peroxidase and polyphenoloxidase along with the estimation of phenols. The significant activity of the above defence enzymes were observed during the advanced stages of infection in

the leaves and no significant changes were observed in the stem tissues. The significant increase in the phenol content was observed at early and advanced stages of disease in leaves and stem respectively (Kuvalekar *et al.*, 2011).

## 2.6 Management of fig rust using chemicals, biorationals and bio agents

### 2.6.1 *In vitro* evaluation of fungicides, biorationals and bioagents

#### 2.6.1.1 *In vitro* evaluation of fungicides

Amaresh and Nargund (2003) evaluated both systemic and non systemic fungicides *in vitro* against uredospore germination of *Puccina helianthii* causal agent of sunflower rust and found that among systemic fungicides propiconazole, hexaconazole, cyperconazole and tridemorph were more effective even at lower concentrations tested (0.025 and 0.05%). Among non systemic fungicides, mancozeb and chlorothalonil were found effective at higher concentration.

Kalappanavar *et al.* (2008) conducted an *in vitro* experiment on efficacy of fungicide against *Puccinia triticina* causing brown rust of wheat. The results revealed propiconazole as the best treatement followed by triadimefon and hexaconazole at 0.1% concentration.

Chaudhary and Chaudhari (2013) reported that among non-systemic fungicides tested against *Puccinia recondita* f. sp. *tritici*, maximum inhibition of uredospores germination was observed in mancozeb (54.85%) followed by chlorothalonil (40.89 %). Among the different concentrations tried, the maximum inhibition of uredospores germination was at 1000 ppm of mancozeb which inhibited 83.33 per cent uredospore germination followed by the same fungicide at 500 ppm (72.31%). Among systemic fungicides, propiconazole found to be the best for inhibition of 86.03 per cent uredospore germination followed by hexaconazole and penconazole with 77.40 and 72.29 per cent, respectively.

Dey *et al.* (2013) evaluated systemic and non-systemic fungicides against *Puccinia sorghi* at different concentrations and found that tebuconazole 250 EC (4.78% uredospore germination) was found to be significantly superior among the eight systemic fungicides evaluated *in vitro.* Among the non-systemic fungicides,

mancozeb + phyton (7.24% uredospore germination) was found to be significantly superior followed by mancozeb (24.44% uredospore germination) at different concentrations.

**2.6.1.2 *In vitro* evaluation of biorationals**

The maximum per cent inhibition of uredospore germination of *Phakopsora pachyrhizi* infecting soybean was found with tobacco leaf extract (88.10%) followed by neem leaf extract (87.21%) and *Clerodendron* leaf extract (66.79 %), as reported by Hundekar (1999). He also reported that all extracts showed antifungal activity against uredospore germination at all concentrations tested. The per cent inhibition reduced with decreased concentration of leaf extract.

Zade *et al.* (2005) conducted an *in vitro* study to determine the efficacy of plant leaf extracts of neem, mehandi, sadaphuli, bael, custard apple and marigold at 50 per cent and 100 per cent against *Puccinia archadis* causing rust disease in groundnut. In which they concluded that neem leaf extract was best at 50 per cent and 100 per cent concentrations, followed by mehandi at 100 per cent.

Subrarmani *et al.* (2012) evaluated four plant extracts *viz., Adhatoda vasica, Azadirachta indica, Lantana camara* and *Ricinus communis* against spore germination of coffee leaf rust pathogen (*Hemileia vastatrix* Berk. & Br.) and found the inhibition of uredospore to an extent of 73.86, 61.40, 69.91 and 50.94 per cent with leaf extracts of *A. vasica, A. indica, L. camara* and *R. communis*, respectively at 15 per cent concentration.

Out of 20 plant extracts tested against *Puccinia recondita* f. sp. *tritici*, maximum inhibition of uredospore germination was recorded in garlic bulb extract followed by onion bulb and ginger rhizome extract with 59.78, 57.70 and 54.81 per cent, respectively (Chaudhary and Chaudhari, 2013).

Dey *et al.* (2013) reported the least uredospore germination of *Puccinia sorghi* at 5 per cent concentration of Neemazol F (6.55%) and Nimbicidine (6.83%) followed by Jeevamruta (22.69%) and Panchagavya (33.67%) at 20 per cent concentration.

Veena *et al.* (2016) tested different bio rationals and bioagents on groundnut rust during *kharif* 2013-14 and found that neam leaf extract + *Pseudomonas*

*fluorescens* recorded 2511 kg/ha which was on par with the treated check and neem leaf extract (2365 kg/ha) was next best treatment which recorded less disease severity of 27.65 and 32.59 PDI respectively.

Mudyiwa *et al.* (2017) reported that out of four botanicals tested against uredospore germination of coffee leaf rust caused by *Hemileia vastatrix, Moringa* was found to have the highest inhibitory effect, though this was not significantly different from lemon grass at 100 per cent. Aloe vera had the lowest spore germination inhibitory effect. It is recommended that high concentrations of plant extracts (50-100%) has to be used in order to ensure effective fungal spore inhibition.

Shabana *et al.* (2017) tested the efficacy of eight plant extracts *viz.*, garlic, clove, garden quinine, brazilian pepper, anti madhaari, black cumin, white cedar and neem at 0.2 per cent (v/v) against the uredospore germination of *Puccinia triticina.* The study revealed that all the treatments inhibited spore germination by more than 93 per cent. Neem seed extract (98.99%) recorded maximum inhibition with no significant difference from the tested fungicide sumi-8 (positive control).

The new formulation Panchaparani extract, bulb extract of *Allium sativum*, leaf extract of *Eupatorium odoratum* and *Ageratum conyzoids* were effectively minimized the uredospore germination of *Uromyces appendiculatus* causing rust of *Lablab purpuereus* (Kamble and Patil, 2017).

#### 2.6.1.3 *In vitro* evaluation of bio agents

Sultana *et al.* (2000) reported that *Verticillium lecanii* as compared to *Cladosporium cladosporioides* infected the rust pustules of *Uromyces appendiculatus* faster and caused them to become whitish due to the sporulation of the biocontrol fungus *V. lecanii*. Microscopic examination of slides with uredospores sprayed with conidial suspension (in water) of the biocontrol agents showed that the hyphae of these fungi grew over the uredinia and penetrated directly. At the time of penetration, the coagulation and disintegration of the cytoplasm was observed.

Zade *et al.* (2005) conducted an *in vitro* study to determine the efficacy of *Trichoderma viride* and *Trichoderma harzianum* 15 days old culture filtrates at 10 per cent, 20 per cent and 30 per cent concentration by spore germination assay. The

culture filtrates of the tested bioagents were found to be effective at 30 per cent in inhibiting the uredospore germination of *Puccinia arachadis.*

Mehfud *et al.* (2006) conducted an *in vitro* study to elucidate the parasitism of *Verticillium psalliotae* on the uredospores of *Hemileia vastatrix.* The results of *in vitro* study revealed the significant reduction in the uredospore germination and the increased germination of the *Verticillium* conidia.

In an *in vitro* experiment to test the efficacy of bioagents in reducing the uredospore germination of *Puccinia sorghi*, it was reported that *Trichoderma harzianum* at 108 spores/ml recorded significantly less per cent germination of uredospores (31.07%) followed by *Bacillus subtilis* (43.42%) and *Pseudomonas flourescens* (53.39%) at 20 per cent concentration (Dey *et al.*, 2013).

Evaluation of bacterial antagonists against *Hemileia vastatrix* (Berk. and Br.) under *in vitro* condition revealed that treatment with *Bacillus subtilis* recorded less uredospore germination (20.03%) compared to *Pseudomonas fluorescens* (22.41%) at the higher concentrations (1 x $10^9$ cfu/ml) tested (Navilekar and Narayanaswamy, 2015).

Marwa and Hassan (2017) isolated naturally occurring antagonistic bioagents on pea leaves free from rust infection and evaluated for their antagonism against *Uromyces pisi*, the causal agent of rust. Isolates of both *Bacillus* spp., *i.e. B. chitinosporus, B. megaterium, B. thuringiensis* and *B. subtilis* and *Trichoderma* spp., *i.e. T. album, T. hamatum, T. harzianum* and *T. viride* were selected, purified and identified. The inhibitory effect of these isolates was assessed *in vitro* on the germination of the uredospores. The inhibitory effect of *Bacillus* spp. ranged between 31.9-42.4 per cent and *Trichoderma* spp. between 34.9-53.5 per cent. In addition, *B.* thuringiensis recorded the highest inhibition of uredospores followed by *B. megaterium* then *B. subtilis* and *B. chitinosporus.* Meanwhile, *T. viride* recorded the highest inhibition followed by *T. harzianum, T. hamatum* and *T. album*.

### 2.6.2 *In vivo* evaluation of fungicides, biorationals and bioagents

#### 2.6.2.1 *In vivo* evaluation of fungicides

Kulkarni and Sharma (1976) reported that compogron-M, plantavax and benodanel were effective in checking the rust on fig leaves when applied at initial

infection, indicating their systemic and curative action. Shinvi and Mishra (1979) studied the efficacy of different fungicides against fig rust (*C. fici*) and found that vitavax (carboxin) at 0.05 per cent was most effective followed by benomyl (benlate) at 0.05 per cent.

Twelve oat cultivars that differed in susceptibility to crown rust caused by *Puccinia coronata* f. sp. *avenae* were evaluated during severe, moderate and light epidemics showed negative correlation between the disease severity and ratios of yield or kernel weight in rusted plots and were highly significant (Singleton *et al.*, 1982).

Benagi (1991) tested eight fungicides against ground nut rust and observed maximum reduction of disease with propiconazole (0.1%).

Nazeer *et al.* (1993) conducted a research trial where they observed that fig rust was effectively controlled by mancozeb (0.2%) and tridemorph (0.1%) followed by propiconazole (0.05 %).

The chlorothalonil (0.2%), bordeux mixture (1.0%), tridemefon (0.1%), carbendazim (0.1%) and mancozeb (0.3%) were reported as effective for controlling the fig rust disease. The cost-benefit ratio observed during the study on management of fig rust was maximum with bordeux mixture (1:17) treatment, followed by carbendazim (1:11), chlorothalonil (1:10) and mancozeb (1:10) (Gaikwad and Nimbalkar, 2004).

Sharma and Mehara (2007) tested seven fungicides *viz.*, Blitox-50 0.2% (copper oxychloride), Baycor (biloxazol), Kavach (chlorothalanil), Dithane-M-45 (mancozeb), Bayleton (tridemelon), Topsin-M (Thiophanate methyl) and Calixin (tridemorph) from 1993-1997 against fig rust caused by *Cerotelium fici*. All fungicides found effective in reducing the disease significantly as compared to the control. Chlorothalonil was found most effective (83.20%) followed by copper oxychloride (80.0%) and were statistically on par.

Eight different fungicides were tested against powdery mildew and rust disease of garden pea at Regional Agricultural Research Station (RARS), Ishurdi and Pabna, Bangladesh during 2006-07. The highest PDI for both diseases was observed

in control treatment, where as the lowest PDI and per cent disease reduction over control was recorded in Sedozole 5 EC (propiconazole) among the other seven tested fungicides (Alam *et al.*, 2007).

Kalappanavar *et al.* (2008) conducted an *in vivo* experiment on efficacy of fungicide against *Puccinia triticina* causing brown rust of wheat. The results revealed propiconazole as the best treatment followed by triadimefon and hexaconazole at 0.1 per cent concentration.

The management of soybean rust through fungicides and botanicals revealed that two sprays of hexaconazole (0.1%) was found effective followed by kresoxim methyl (0.1%) along with azadirachtin (0.5%) and two sprays of kresoxim methyl (0.1%) in reducing disease severity and increasing the seed yield with better economic returns (Devaraj and Jahagirdar, 2013).

Capucho *et al.* (2013) evaluated a new strategy to control leaf rust in Canilon coffee in Brazil through the application of triazole fungicides in soil and then to estimate the damage caused by the disease after treatment during November 2008 to May 2011. The treatments with the applications in the soil were effective in controlling the disease; however, through the joint analysis of the disease control and productivity, the best treatments were those that used ciproconazol or flutriafol in the soil, with or without foliar spray treatments.

Among the different fungicides used against coffee leaf rust, Thifluzamide 24 SC at 1 ml/litre concentration was found to be more effective in managing the disease and was on par with Bayleton at 1g/l and oxycarboxin at1 g/l (Navilekar and Narayanaswamy, 2015).

The fungicide Topas was reported as superior in reducing pea rust severity and the substantial increase in the yield over the control was reported (Marwa and Hassan, 2017).

#### 2.6.2.2 *In vivo* evaluation of biorationals

Ganapathy and Narayaaswami (1990) noticed that neem oil from *Azadirachta indica* and leaf extracts of *Nerium odorum* reduced the incidence of rust, late leaf spot and ring mosaic of groundnut.

Kalappanavar *et al.* (2008) reported that neem leaf extract (10%) and Panchagavya (15%) were effective in controlling brown rust of wheat.

Foliar spray application of wheat plants with garlic, clove, garden quinine, brazilian pepper, anti madhaari, black cumin, white cedar and neem at 0.2 per cent (v/v) had significantly reduced the leaf rust infection compared with untreated control and neem seed extract was reported as the most effective treatment (Shabana *et al.*, 2017).

Kamble and Patil (2017) reported that in the field trial for the management of lablab rust disease caused by *Uromyces appendiculatus*, the new formulation panchaparani extract (10.94), *Allium sativum* (bulb extract) (16.00) and *Eupatorium oderatum* (18.68) showed least Per cent Diseased Index (PDI) compared to the control (44.15).

**2.6.2.3 *In vivo* evaluation of bioagents**

Subrahmanyam *et al.* (1990) reported that *Verticillium lecanii* was found parasitizing rust, early and late leaf spot pathogens of peanut in the glasshouse at ICRISAT Center and in the farmers fields of Andhra Pradesh, Karnataka and Tamil Nadu. In inoculation experiments, there was a significant reduction in the extent of rust and late leaf spot development on peanut leaves inoculated with *V. lecanii*.

Antibiotic production was clearly indicated as the mode of action of *in vivo* biocontrol by *Baciilus subtilis* strain CL27 against damping off caused by *Botrytis cinerea* of *Astilbe* micro-plants, because a u.v.-induced antibiotic negative mutant strain CL27b showed no activity in seedling bioassays *in vivo*. Also the mutant strain CL27a, which produced the two peptide antibiotics but had lost the ability to produce the non-peptide antibiotic greatly reduced *in vivo* activity (Leifert *et al.*, 1995).

Yuen *et al.* (2001) evaluated 120 bacterial strains were evaluated for control of bean rust caused by *Uromyces appendiculatus* under green house conditions. The strains found previously antagonistic to some fungal pathogens, were isolated from dry edible bean (*Phaseolus vulgaris*) and other hosts. Only *Pantoea agglomerans* B1, from bean blossom and *Stenotrophomonas maltophilia* C3, a chitinolytic strain from a Kentucky bluegrass leaf were effective in multiple experiments in reducing bean rust

severity. The addition of colloidal chitin to C3 cell suspensions and treatment with chitin broth cultures were evaluated as methods to improve biocontrol efficacy of C3. While chitin amendments increased the rust control in the greenhouse as compared to C3 cells in buffer, chitin broth cultures gave the highest and longest-lasting level of control.

Sheroze *et al.* (2003) conducted an *in vivo* study using the five biocontrol agents *viz.*, *Vetricillium lecanii*, *Paecilomyces fumosoroseus*, *Beauveria bassiana*, *Cladosporium cladosporoides* and *Metarrhizium anisopliae* in combination for the reduction of leaf rust disease severity in wheat cased by *Puccinia triticina*. Among the different combinations evaluated, *V. lecanii* with *P. fumosoroseus* and *B. bassiana* resulted in the reduction of leaf pustule development.

The *in vivo* study conducted by spraying with *Verticillium* 24 h before inoculation of *Hemileia* demonstrated the parasitism of *Verticillium* and reduced disease severity of coffee leaf rust (Mehfud *et al.,* 2006).

Kalappanavar *et al.* (2008) reported that *Trichoderma harzianum* at 0.75 per cent controlled the brown rust of wheat effectively.

Under greenhouse conditions, spraying of pea plants with any of *Bacillus* spp. and *Trichoderma* spp., 48 h before inoculation with *Uromyces pisi* on the plants grown from seeds soaked with or without 20 mM of antioxidant bion (BTH) significantly reduced the severity of the disease in the range of 4.0–5.4, 12.0-15.8%, respectively compared with the control (48.7%) (Marwa and Hassan, 2017).

# 3. MATERIAL AND METHODS

The present investigation on the fig rust caused by *Cerotelium fici* (Cast.) Arth. was conducted both in the laboratory and field conditions. The laboratory studies were carried out at Department of Plant Pathology, College of Horticulture, Bagalkot during 2017-18. The *in vivo* studies involving screening of fig varieties and field evaluation of effective treatments were conducted at Sector No 70, UHS, Bagalkot and Horticulture Research and Extension Centre, Tidagundi, Vijayapura respectively. The details of the materials and the methodology adopted for the research is presented in this chapter.

## 3.1 Survey for fig rust severity in major fig growing regions of North Karnataka

A roving survey was carried out in major fig growing areas of Bagalkot, Koppal and Bidar districts of North Karnataka. Per cent disease index (PDI) was calculated using the formula given by Wheeler (1969). The rust severity recorded by using 0 – 9 grade scale (Prakashan and Thamburaj, 1991).

**Scale (0-9) for recording observations**

| Rating | Description | Per cent leaf area covered |
|---|---|---|
| 0 | No symptoms on leaves | Nil |
| 1 | Minute orange coloured pustules | < 1 |
| 3 | Typical brown coloured pustules | 1-10 |
| 5 | Typical brown coloured pustules | 11-25 |
| 7 | Typical brown coloured pustules | 26-50 |
| 9 | Typical brown coloured pustules | > 51 |

$$\text{Per cent disease index} = \frac{\text{Sum of all individual disease ratings}}{\text{Number of sample}} \times \frac{100}{\text{Maximum disease grade}}$$

### 3.2 Symptomatology

The infected leaf, fruit and petioles were observed *in planta*. The hand sections of the infected portion of the leaf, petiole and fruit was made using glass slide, blade, needle, cover slip and lactophenol, while preparing permanent slides for further observations. The prepared samples were observed under the binocular research microscope. The leaves were also observed under the dissecting microscope (stereomicroscope).

### 3.3 Inoculum

The fresh uredosori were collected from the diseased fig leaves from Fruit orchard, UHS, Bagalkot in the early morning for conducting pathogenicity test and other *in vitro* studies. The spores on the abaxial surface of the leaf was carefully brushed off using paint brush No. 10 on to the white clean paper, which was then collected in to 2 ml eppendorf tubes.

### 3.4 Proving pathogenicity

The five months old fig saplings were choosen for the pathogenicity test. In each plant, four leaves were inoculated (Plate 6) and other leaves left as control since the infection is local. Four methods of inoculation were tested. They are dusting, leaf pinning, plaster method and spray inoculation. For dust method of inoculation the uredospores collected were simply dusted by twisting the leaf downwards. For leaf pinning method, the infected leaf sample of size 2 $cm^2$ was pinned using the black enamelled insect pins so that the abaxial surface of the leaf comes in contact with the inoculum. The one inch surgical tape (adhesive tape) was dusted with the uredospores and pasted on to the lower surface of the leaf, in plaster method. For the spray inoculation method, the spore suspension was prepared. The spore concentration was adjusted to $6.8\times10^4$ spores per ml using haemocytometer and sprayed using the hand sprayer. Plants were inoculated in the early morning to facilitate the infection. The inoculated seedlings were covered with polythene bags along with moist cotton swab inside and were kept for 48 h for mist development to ensure successful penetration of the uredospore into the tissue. The polythene bags were removed after 2 days of post inoculation. Observations were made regularly for the appearance and development of symptoms.

## 3.5 Effect of sugars, temperature and relative humidity on uredospore germination of *Cerotelium fici*

### 3.5.1 Effect of sugars on uredospore germination

*In vitro* studies were conducted to assess the effect of sugars (*viz.*, dextrose and sucrose), temperature and relative humidity on uredospore germination of the *C. fici.*

The germination of uredospores studied in tap water, RO water, distilled water and the water agar (0.5%) containing sucrose (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0%) and dextrose (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0%) using cavity slide method.

Rust infected fig leaves having more number of pustules were collected. Spores from the leaf surface transferred to the eppendorf tubes to which the respective media added and vortexed to get the spores finely distributed in the media. Later 200 µl of the suspension was transferred to the cavity slides. The ambient temperature of 25 ˚C and 85 per cent RH was maintained throughout the experiment. The observations recorded after 24 hours by counting number of spores per microscopic field (10 X magnification) and four such microscopic fields were counted. The spores producing the germtube twice their size was considered as germinated. The per cent germination was calculated by counting numbers of spores germinated to total number of spores observed using the formula,

$$\text{Per cent spore germination} = \frac{\text{No. of uredospores germinated}}{\text{Total No. of uredospores observed}} \times 100$$

### 3.5.2 Effect of temperature on uredospore germination

The cardinal temperature required for spore germination was carried out using cavity slide method. Uredospore suspension prepared in water agar (0.5% agar) containing 2.5 per cent sucrose. The cavity slides kept in the petriplates lined with the moistened blotting paper incubated at temperature ranging from 10 to 40 °C in an incubator for 24 h. Three replications were maintained for each temperature and the observations were recorded after 24 h. The per cent spore germination was calculated as mentioned in 3.5.1.

### 3.5.3 Effect of relative humidity on uredospore germination

Two hundred µl of spore suspension prepared in water agar containing 2.5 per cent sucrose solution was taken on a cavity slide. The cavity slides were kept in the moist chamber and were incubated at 25 ˚C by maintaining the different relative humidity levels *viz.*, 60, 65, 70, 75, 80, 85, 90 and 95 per cent by dissolving 38, 36, 33, 30, 27, 23, 18 and 11 per cent concentrated sulphuric acid ($H_2SO_4$) respectively in the desiccators containing distilled water. 100 per cent relative humidity was obtained by adding no sulphuric acid to the distilled water in a desiccator (Solomon, 1951). Three replications were maintained for each treatment. Uredospore germination was observed after 24 h of incubation. The per cent germination was calculated as mentioned in 3.5.1.

## 3.6 Screening of fig varieties for resistance to rust disease

### 3.6.1 Screening of fig varieties for resistance to rust disease under natural epiphytotic condition

Fig varieties *viz.*, Bellary, Conadriya, Dienna, Dinakar, Excel and Poona were tested for their resistance to rust disease under natural epiphytotic conditions at Fruit orchard, UHS, Bagalkot. The screening was carried out from the 2$^{nd}$ week of October, 2017 to the 2$^{nd}$ week of May, 2018. Five plants of each variety in which bottom, middle and upper leaves of five shoots were observed for rust severity. The per cent disease index was calculated using the formula mentioned in 3.1.

**Scale (0-9) for recording observations**

| Rating | Description | Per cent leaf area covered | Resistance / Susceptibility |
|---|---|---|---|
| 0 | No symptoms on leaves | Nil | **HR** |
| 1 | Minute orange coloured pustules | <1 | **R** |
| 3 | Typical brown coloured pustules | 1-10 | **MR** |
| 5 | Typical brown coloured pustules | 11-25 | **MS** |
| 7 | Typical brown coloured pustules | 26-50 | **S** |
| 9 | Typical brown coloured pustules | >51 | **HS** |

### 3.6.2 Area under disease progress curve (AUDPC)

The disease free and young leaves were tagged on all the six fig varieties for periodical observations. Likewise, the observations for rust severity and progress of disease were recorded at weekly interval from appearance of disease on tagged leaves of five shoots from randomly selected five fig plants. The per cent disease intensity was calculated as mentioned in 3.1.

The area under disease progress curve (AUDPC) was calculated by using the formula given by Wilcoxson *et al.,* 1986.

$$AUDPC = \sum_{i=1}^{K} \frac{(X_1 + X_{i-1})}{2} \times d$$

Where,

$X_i$ = Rust severity at the end of $i^{th}$ observation

K = Number of successive evaluations of rust severity

d = Interval between two evaluations in days

**Rate of infection (r)**

The rate of infection (r) was worked out by using the formula given by Van der Plank (1963).

$$\text{'r' per day} = \frac{2.3}{(t_2 - t_1)} \log \frac{X_2}{X_1}$$

Where,

$X_1$ = Per cent disease intensity at $t_1$ date

$X_2$ = Per cent disease intensity at $t_2$ date

$t_2 - t_1$ = Time interval in days between two observations

### 3.6.3 Simple linear correlation and regression analysis

The disease severity of six fig varieties was correlated with the weather parameters like relative humidity (morning and afternoon in %), temperature (maximum and minimum in ˚C) and rainfall (mm). The meteorological data was

collected from Agro-meteorology Division, Main Horticultural Research and Extension Centre, UHS, Bagalkot was averaged at seven days interval for the same week of disease severity, at seven days interval one week prior to the observed disease severity and at seven days interval two weeks prior to the observed disease severity.

The meteorological parameters averaged at periodical intervals as mentioned above were subjected to regression analysis, wherein multiple linear regression was carried out.

### 3.6.4 Biochemical studies

The influence of disease on the biochemical parameters of the leaf such as total sugars, reducing sugars, total soluble protein, total phenols, chlorophyll content (chlorophyll a, Chlorophyll b and total chlorophyll) and epicuticular wax were studied. The leaf samples for the estimation of the above mentioned biochemical parameters were collected from the six varieties used for screening. The upper ($2^{nd}$ node) and lower ($2^{nd}$ node) leaves were collected from each variety from the same plant at 30 days interval at a frequency of three from the diseased plants and healthy plants from Fruit orchard, UHS, Bagalkot. The collected leaves were preserved at -20˚ C during the study period. The reducing sugars and total sugars were estimated by Dinitrosalicylic acid (DNS) and Anthrone reagent method (Sadasivam and Manickam, 1996) respectively. The concentration of non reducing sugars in the leaf was obtained by substracting the total sugars from reducing sugars. The total soluble protein content was determined by following the procedure described by Lowry *et al.* (1951). Total phenols present in the leaf samples were analysed by the Folin-Ciocalteau reagent method (Sadasivam and Manickam, 1996). The chlorophyll content was estimated following the modified dimethyl sulphoxide (DMSO) method described by Hiscox and Israelastam, 1979. The epicuticualr wax estimation was done using the colorimetric method (Ebercon, 1977).

### 3.6.4.1 Estimation of reducing sugars by dinitrosalicylic acid method

The reducing sugars present in the leaves were estimated using DNS method.

**Materials**

**Dinitro salicylic acid reagent**: Dissolve by stirring one g dinitrosalicylic acid, 200 mg crystalline phenol and 50 mg sodium sulphite in 100 ml of one per cent NaOH and stored at 4 ˚C.

**40% Rochelle salt**: Prepared by dissolving 40 g potassium sodium tartarate in 100 ml water.

**Standard glucose solution**: Prepare 100 mg of glucose in 100 ml of distilled water in a volumetric flask.

**Methodology:**

Hundred mg of the leaf sample was weighed and crushed with hot solution of 80 per cent ethanol twice (5 ml each time). The extract was centrifuged at 12,000 rpm for 14 minutes and the supernatant was collected. The test tubes containing the supernatant were kept in the boiling water to allow the evaporation of ethanol. The sugars present in the tubes dissolved by adding 10 ml distilled water. One ml of the extract was pippetted out. Standards were prepared by taking 0, 50, 150, 250, 350, 450 and 550 µl of the standard glucose solution. '0' served as blank and the volume made up to 1.5 ml by adding distilled water. 1.5 ml of DNS reagent was added and then the contents were heated in boiling water for about five minutes. When the contents of the test tube were still warm, 0.5 ml of 40 per cent rochella salt solution was added. After the cooling of the test tubes, the absorbance of the dark red colour was taken at 510 nm. The reducing sugar content was obtained by plotting the standard graph using the glucose standards.

### 3.6.4.2 Estimation of total sugars

Total sugar content was estimated by Anthrone Reagent method (Sadasivam and Manickam, 1996).

**Materials**

- **2.5 N HCl**
- **Anthrone reagent**- 200 mg of anthrone was dissolved in 100 ml ice cold 95 per cent $H_2SO_4$. The Reagent was prepared fresh before use.
- **Standard glucose solution**: 100 mg of glucose was dissolved in 100 ml distilled water.

**Procedure**

Hundred mg of leaf sample was grinded using 5 ml of 2.5 N HCl. The samples extracted in the test tubes were kept in water bath at 100 ˚C for about three hours. As sodium carbonate was added the effervescence was observed and sodium carbonate was added pinch by pinch until the effervescence was ceased. The contents were centrifuged at 12,000 rpm for ten minutes and the supernatant was collected. The volume of aliquot was made to 10 ml and from this 50 µl was pipetted out. Standards were prepared by taking 0, 100, 150, 200, 250 and 300 µl of the standard glucose solution. '0' served as blank. All the aliquots were made up to 2.5 ml by adding distilled water. Then 5 ml of anthrone reagent was added slowly and the contents were stirred gently using the glass rod. The test tubes were heated in a boiling water bath for 8 minutes. Then the test tubes were cooled rapidly and the green to dark green colour developed was read at 630 nm. The standard graph was prepared by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. The amount of total sugar present in the sample was calculated using standard graph.

**3.6.4.3 Estimation of total phenols**

The phenols present in the samples were estimated by Folin-Ciocalteau reagent method (Sadasivam and Manickam, 1996).

**Materials**

- **80 % Ethanol**
- **Folin-Ciocalteau reagent**: Commercial grade reagent was diluted in 1:1 with water

- **20 per cent sodium Carbonate solution**: 20 g of $Na_2CO_3$ was dissolved in water and volume was made up to 100 ml

- **Stock catechol solution**: The stock solution was prepared by dissolving 50 mg in 1 ml of ethanol and volume was made up to 50 ml using distilled water. The working standard was prepared by pipetting 5 ml from the stock and volume was made up to 100 ml (0.05 mg catechol in 1 ml).

**Procedure**

Hundred mg of the leaf sample was grinded in 5 ml of 80 per cent ethanol and centrifuged at 10000 rpm for 20 minutes. The supernatant was pooled and 0.1 ml of the supernatant was evaporated on a water bath. For the preparation of standard graph 0.1, 0.2, 0.3, 0.4 and 0.5 ml of the working standard was pipetted out in to the test tubes. The volume of all the aliquots were made up to 3 ml using distilled water and shaken well followed by addition of 0.5 ml of Folin-Ciocalteau reagent (1:1). After 3 minutes, 2 ml of 20 per cent sodium carbonate was added to each tube and mixed thoroughly and incubated for 30 minutes. The absorbance was measured at 650 nm. Using the standard curve the phenol concentration was calculated.

**3.6.4.4 Estimation of total proteins**

**Materials**

- 2 per cent sodium carbonate ($Na_2CO_3$) in 0.1N NaOH (Reagent A)

- 0.5 per cent $CuSO_4.5H_2O$ in 1.0 per cent potassium sodium tartrate (Reagent B)

- **Alkaline Copper solution**: 50 ml of reagent A was mixed with 1 ml of Reagent B prior to use (Reagent C)

- **Folin-Ciocalteau reagent**: Commercial grade reagent was diluted 1:1 with water

- **Protein solution (Stock standard)** : 50 mg of bovine serum albumin was weighed and it was dissolved in distilled water and the volume was made up to 50 ml in a standard flask.

- **Working standard**: 10 ml of stock standard was diluted to 50 ml with distilled water in a standard flask. One ml of the working standard thus had 200 µg proteins.

**Procedure**

Total protein content was estimated by using the method suggested by Lowry *et al.* (1951). Five hundred mg of leaf sample was homogenized by adding 5-10 ml of sodium potassium buffer. The homogenate was centrifuged at 12,000 rpm for 15 min at 4 °C. From the supernatant obtained, 0.2 ml sample were drawn into separate test tubes and the volume was made up to 1 ml by adding sterile distilled water. Tube with 1 ml water served as blank. To each tube 5.0 ml of alkaline copper solution was added and mixed well and allowed to stand for 10 minutes. Then 0.5 ml of Folin-Ciocalteau reagent (1:1) was added, mixed well and incubated at room temperature for 30 min in the dark. The blue colour developed was read in spectrophotometer at 660 nm. Using a standard graph plotted from concentrations of bovine serum albumin, the protein in the sample was estimated and was expressed as mg per g of fresh leaf.

**3.6.4.5 Estimation of chlorophyll content**

Approximately 100 mg of leaves were cut into small pieces and added separately to the test tubes containing 7 ml of DMSO along with one blank DMSO without adding any leaf sample. The test tubes were heated at 65 ˚C for three hours in a hot air oven. Extract was collected by discarding the leaf sample by filtering using whatman filter paper 1. Then the volume was made up to 10 ml with DMSO. Optical density of the extract was measured at 645 and 663 nm using DMSO as blank. The amount of chlorophyll was calculated using the following equations by Arnon (1949).

$$\textbf{Chlorophyll a (mg/g)} = 12.7\,(A_{663}) - 2.69\,(A_{645}) \times \frac{V}{1000} \times \frac{1}{\text{Fresh weight}}$$

$$\textbf{Chlorophyll b (mg/g)} = 22.9\,(A_{645}) - 4.65\,(A_{663}) \times \frac{V}{1000} \times \frac{1}{\text{Fresh weight}}$$

$$\textbf{Total chlorophyll (mg/g)} = 22.2\,(A_{645}) + 8.02\,(A_{663}) \times \frac{V}{1000} \times \frac{1}{\text{Fresh weight}}$$

### 3.6.4.6 Estimation of epicuticular wax content in fig leaves

The leaf wax was determined by the colorimetric method.

**Materials**

- **Chloroform**
- **Acidic dichromate reagent**: Prepared by mixing 40 ml of deionised water with 20 g powdered potassium dichromate. The resulting slurry was mixed with one litre concentrated sulphuric acid and heated (below boiling point) until a clear solution was obtained.
- **Standard carbowax**: Hundred mg of carbowax 4000 was dissolved in 10 ml chloroform and the working standard was prepared at concentration of one mg carbowax per ml of choloroform.

**Procedure**

The individual sample consisting of ten leaf discs each of 5 mm diameter was immersed in 15 ml chloroform for 15 seconds. The extract was filtered and evaporated to dryness on a boiling water bath until the smell of chloroform goes. The standards prepared by pippetting out 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of working standard and 0 served as blank. Five ml of acidic dichromate was added and allowed to stand for 30 min in the boiling water. 20 ml of deionised water was added and incubated for 15-20 minutes for the colour development and optical density of the sample read at 590 nm.

## 3.7 Management of fig rust using fungicides, biorationals and bioagents

### 3.7.1 *In vitro* evaluation of fungicides, biorationals and bioagents

The inhibitory effect of fungicides on uredospore germination was evaluated using the cavity slide method in which the spore suspension was prepared in water agar (0.5%) containing 2.5 per cent sucrose and the experiment was laid out using completely randomized design (CRD). Systemic fungicides were tested at 250, 500 and 1000 ppm, contact fungicides were evaluated at 500,1000, 2500 and 3000 ppm, whereas fungicide combinations were evaluated at 500, 1000, 1500, 2000 ppm listed

in Table 1. The fungicides and their respective concentrations were prepared by mixing the requisite quantities of fungicides with two times (double concentration) in the distilled water. Single drop of uredospore suspension was placed in the wells of series of cavity slides by using one ml pipette to which single drop of different fungicides (double concentration) was also added to get the required concentrations. Treatment without fungicide served as control. Cavity slides containing spore suspension were incubated at 25±1˚ C. Three replications of each treatment were maintained and the germinated and ungerminated spores were counted in four microscopic fields for each slide after 24 h incubation. Per cent inhibition of spore germination was calculated as per the formula described by Vincet (1947).

$$I = \frac{C - T}{C} \times 100$$

Where,

I = Per cent inhibition

C = No. of spores germinated in control

T = No. of spores germinated in treatment

The per cent values were transformed to arc sine values and later the data was analyzed statistically.

**3.7.1.2 *In vitro* evaluation of biorationals**

The plant extracts (Table 2), crude vegetable oils, Neem Seed Kernel Extract (NSKE) and amrut pani were evaluated using completely randomized design. The seven plant extracts belonging to different families were evaluated for inhibition of uredospore germination *in vitro*. Fresh plant materials of seven botanicals were collected and washed first in tap water and then in distilled water and allowed for water to drain off. 100 g plant sample of each plant species crushed in 100 ml distilled water in a pestle and mortar to obtain 1:1 (w/v) extract. The extracted material was filtered through double layered muslin cloth. The filtrate thus obtained was used as stock solution. Double the required concentration was prepared. To obtain 15, 10,

**Table 1: List of the fungicides used in the study**

| Sl. No. | Chemical name | Trade name |
|---|---|---|
| | **Systemic fungicides** | |
| 1 | Azoxystrobin 23% SC | Amistar |
| 2 | Carbendazim 50% WP | Bavistin |
| 3 | Difenconazole 25.0% EC | Score 250 SC |
| 4 | Hexaconazole 5% EC | Contaf |
| 5 | Kreoxim methyl 44.3% SC | Ergon |
| 6 | Propiconazole 25% EC | Tilt |
| 7 | Tebuconazole 25.9% EC | Folicur |
| | **Non systemic fungicides** | |
| 1 | Chlorothalonil 75% WP | Kavach |
| 2 | Copper hydroxide 35% WG | Kocide 2000 |
| 3 | Copper oxychloride 50% WP | Blue copper |
| 4 | Mancozeb 75% WP | Indofil M-45 |
| 5 | Zineb 75% WP | Indofil Z-78 |
| | **Fungicide combinations** | |
| 1 | Captan 70% + Hexaconazole 5% WP | Taqat |
| 2 | Tebuconazole 50% + Trifloxystrobin 25%WG | Nativo |
| 3 | Carbendazim 12% + Mancozeb 63% WP | Saaf |

**Table 2: List of the plant extracts used in the study**

| Sl. No. | Common name | Scientific name | Family | Part used |
|---|---|---|---|---|
| 1 | Castor | *Ricinus communis* | Euphorbiaceae | Leaf |
| 2 | Datura | *Datura stromonium* | Solanaceae | Leaf |
| 3 | Garlic | *Allium sativum* | Amaryllidaceae | Bulb |
| 4 | Ginger | *Zingiber officinale* | Zingiberaceae | Rhizome |
| 5 | Lantana | *Lantana camara* | Verbenaceae | Leaf |
| 6 | Neem | *Azadirachta indica* | Meliaceae | Leaf |
| 7 | Periwinkle | *Catharanthus roseus* | Apocynaceae | Leaf |
| 8 | Tulasi | *Ocimum tenuiflorum* | Lamiaceae | Leaf |

5 per cent concentration 30, 20 and 10 ml of the stock solution was added to 70, 80, 90 ml distilled water. The inhibitory effect of the plant extracts were evaluated using the cavity slide method. The observations for spore germination were recorded and inhibition per cent was worked out as described in 3.7.1. The crude coconut oil, neem oil and safflower oil were evaluated *in vitro* same as the plant extracts. A control was kept consisting of only uredospore suspension.

**Neem Seed Kernel Extract (NSKE)**

The Neem Seed Kernel Extract (NSKE) required for the evaluation was prepared by grinding 5 g neem seed kernel and soaking the ground powder in 100 ml distilled water for overnight (Mohan *et al.*, 2018). The extract obtained was considered as stock solution from which the required concentrations were prepared and evaluated using the cavity slide method.

**Amrutpani**

One liter of amrut pani was prepared in the mud pot by mixing 1.25 g ghee, 2.5 g honey and 50 g cow dung thoroughly. The mixture was kept for about three days by stirring intermittently (Annon., 2015). The solution obtained by filtering, using double layered muslin cloth was used for the evaluation by using cavity slide method same as the plant extracts.

**3.7.1.3 *In vitro* evaluation of bioagents**

The bioagents *viz.*, *Lecanicillium lecanii*, *Bacillus subtilis* and *Pseudomonas fluorescens* collected from Bio control laboratory, UHS, Bagalkot, were evaluated using cavity slide method for their inhibitory effect on the uredospore germination of *C. fici*. *Lecanicillium* conidial suspension was prepared from two week old pure culture on potato dextrose agar (PDA) and at concentrations *viz.*, $1\times10^2$, $1\times 10^3$ and $1\times 10^4$ cfu per ml. The bacterial cell suspension of *B. subtilis* and *P. fluorescens* was prepared from 2 days old culture at concentrations $10^5$, $10^6$ and $10^7$ cfu per ml. The uredospore suspension of *C. fici* incubated along with prepared suspensions of bio agents as mentioned in 3.7.1.

### 3.7.2 *In vivo* evaluation of fungicides, biorationals and bioagents

#### 3.7.2.1 Field evaluation of fungicides

Field experiment on the efficacy of fungicides against rust disease caused by *C. fici* on fig was carried out at HREC, Vijayapura (Tidagundi). Totally nine fungicides found promising during *in vitro* evaluation were evaluated under field conditions.

**The different treatments imposed were as follows**

| Treatments | Fungicides | Concentration (%) |
|---|---|---|
| $T_1$ | Azoxystrobin 23% SC | 0.1 |
| $T_2$ | Captan 70% + Hexaconazole 5% WP | 0.1 |
| $T_3$ | Carbendazim 50 % WP | 0.1 |
| $T_4$ | Difenconazole 25% EC | 0.1 |
| $T_5$ | Hexaconazole 5% WP | 0.1 |
| $T_6$ | Kresoxim methyl 44.3% SC | 0.1 |
| $T_7$ | Mancozeb 75% WP | 0.25 |
| $T_8$ | Propiconazole 25 % EC | 0.1 |
| $T_9$ | Tebuconazole 250 % EC | 0.1 |
| $T_{10}$ | Control (water spray) | |

**Experimental details**

| | |
|---|---|
| Treatments | 10 |
| Replications | 3 |
| Design | RBD |
| Location | HREC, Tidagundi, Vijayapura |
| Variety | Dinakar |
| Spacing | 5m×3m |

Totally four sprays of each treatment were given after the first appearance of the disease symptom at an interval of 10 days. Observations on disease severity were recorded in each treatment using disease score as mentioned in 3.1 after 5 days of each spray. Finally the Per cent Disease Index was calculated by using the formula mentioned earlier.

**3.7.2.2 *In vivo* evaluation of biorationals and bioagents.**

The plant extracts, vegetable oils, bio agents and amrut pani were evaluated under the field conditions at Fruit orchard, UHS, Bagalkot. The plant extracts were prepared as mentioned in 3.7.1.2. The crude oils *viz.*, safflower oil and neem oil were sprayed by after adding spreader (Nutriwet) at 5 ml/l of water. The bio agent *L. lecanii* formulation was obtained from Biocontrol lab, UHS, Bagalkot and the commercial formulation of *B. subtilis* (Milastin) was used for spraying. The amrut pani was prepared in the same manner as described earlier in 3.7.1.2.

| Treatments | Bioagents/ Botanicals | Concentration (%) |
|---|---|---|
| $T_1$ | *Lecanicillium lecanii* | 0.6 |
| $T_2$ | *Bacillus subtilis* | 0.6 |
| $T_3$ | Ginger rhizome extract | 15 |
| $T_4$ | Garlic bulb extract | 15 |
| $T_5$ | Amrut pani | 5 |
| $T_6$ | Safflower oil | 5 |
| $T_7$ | Neem oil | 5 |
| $T_8$ | Control (water spray) | - |

In total two sprays were given in the month of March, 2018 at ten days interval. The observation on disease severity was recorded at five days interval after each spray as mentioned in 3.1. The Per cent Disesae Index (PDI) was caluculated as mentioned earlier.

**Experimental details**

| | |
|---|---|
| Treatments | 8 |
| Replications | 3 |
| Design | RBD |
| Location | Fruit orchard, UHS, Bagalkot |
| Variety | Bellary |
| Spacing | 5m×3m |

**Yield parameters**

The fruits were harvested at maturity stage at irregular intervals. The number of fruits and weight of the harvested fruits per plant were recorded for each treatment separately and the fruit yield per hectare was calculated.

**Benefit cost ratio (B:C ratio)**

Total cost incurred for the application of each treatment was worked out. Gross returns was calculated on the basis of prevailing market price of the produce during the harvesting season. Net returns were calculated by deducting the total cost from the gross return. Benefit cost ratio was calculated by using the formula.

$$\text{B: C ratio} = \frac{\text{Gross returns (Rs./ha)}}{\text{Total cost (Rs./ha)}}$$

# 4. EXPERIMENTAL RESULTS

The results of the present investigation on fig rust caused by *Cerotelium fici* (Cast.) Arth. was carried out with the objectives of survey, standardization of spore germination assay, screening of fig varieties for resistance to rust and management of fig rust are presented here under.

## 4.1 Symptomatology

During the study the regular observations were made on appearance of fig rust disease in natural field conditions for understanding the symptoms.

The symptoms of rust disease were noticed on leaves, petioles, shoots and fruits. The leaves are the most infected plant part. The upper leaves at the tip of the shoot remained free from the disease. The lower leaves showed prominent rust symptoms.

The earliest symptoms of fig rust appeared as small, elongated yellowish spots or flecks visible on adaxial surface of the leaf (Plate 1a), followed by the development of brownish pustules on the corresponding abaxial surface of the leaf (Plate 1b & 2a). As the disease progressed spots enlarged into roughly circular to irregular brownish spots which were quite conspicuous on the adaxial surface (Plate 1c). Consequently, the pustules burst opened by rupturing the epidermal wall to release the brown uredospore mass on the abaxial surface of the leaf. The dusty uredospores covered the entire abaxial surface of the leaf during severe infection (Plate 1d). Sometimes the pustules were concentrated along the margin of the leaf blade (Plate 1e). Under severe infestation, the entire phylloplane was covered with rust lesions that resulted into twisting of leaf upwards, drying and premature defoliation (Plate 1f).

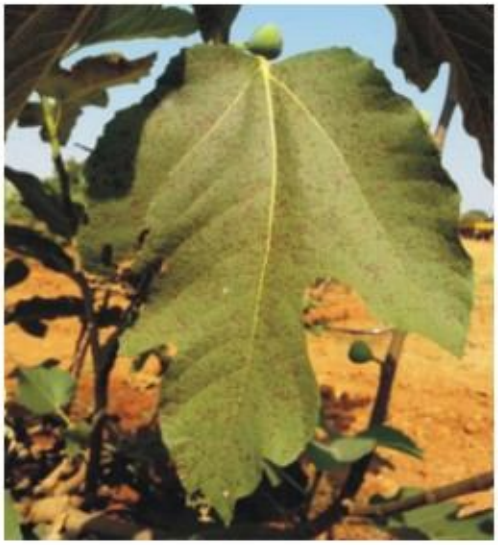
On petioles and shoots, the brown elongated narrow spots were observed and these spots were not erupted and uredospores were not formed (Plate 3a & 3b). Under congenial conditions the fruits were also severely infested (Plate 4a). The thin hand sections of the infected portion of fruit clearly showed the presence of the uredium and uredospores (Plate 4b).



1a. Initial yellowing on adaxial surface



1b. Erupted pustules on abaxial surface



1c. Browinsh spots on adaxial surface



1d. Pustules on abaxial surface

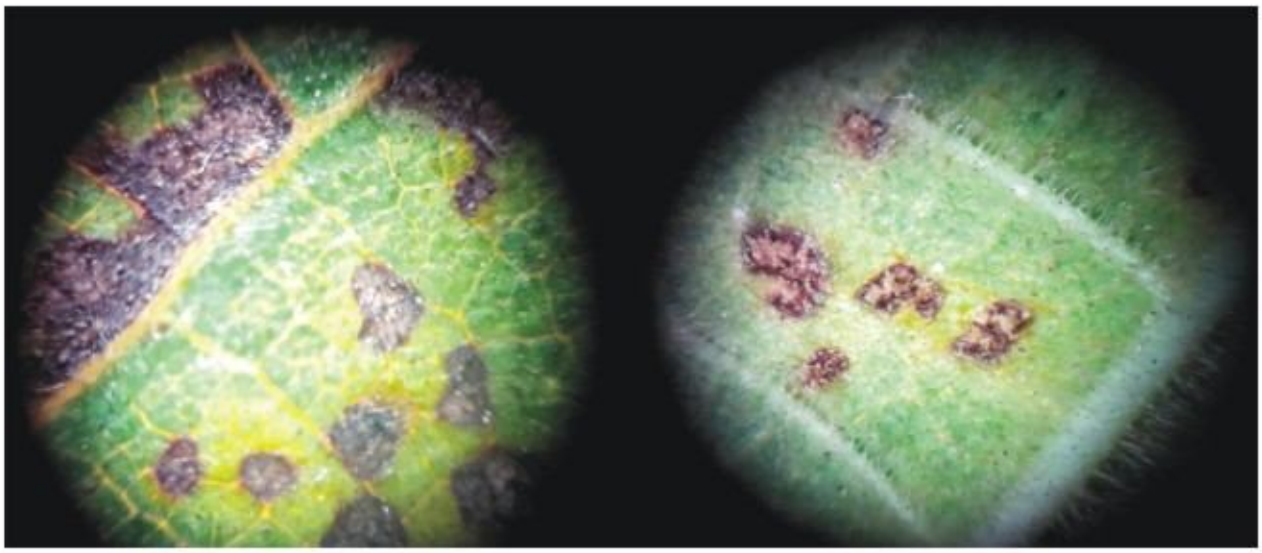


1e. Rusting along margin

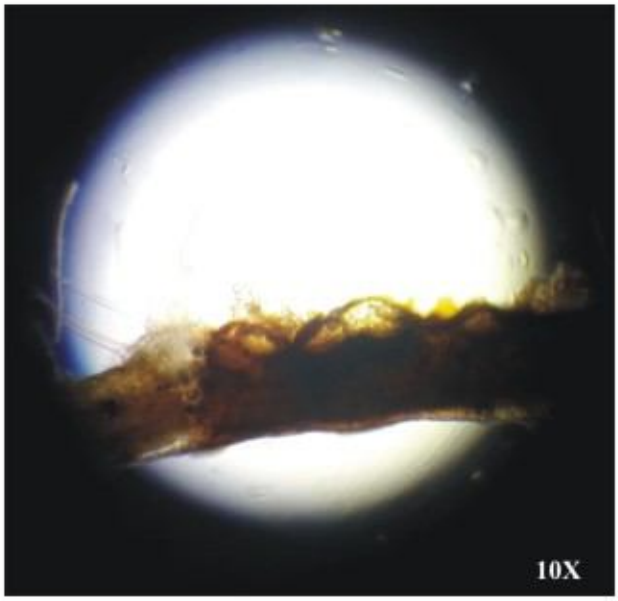


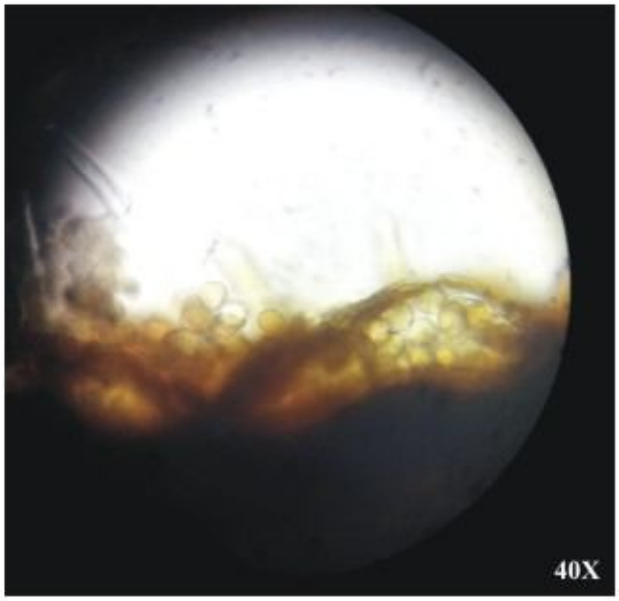
1f. Drying of leaves

**Plate 1. Symptoms on leaf**



**2a. Irregular brown necrotic spots on upper surface and corresponding lower portion showing pustules**



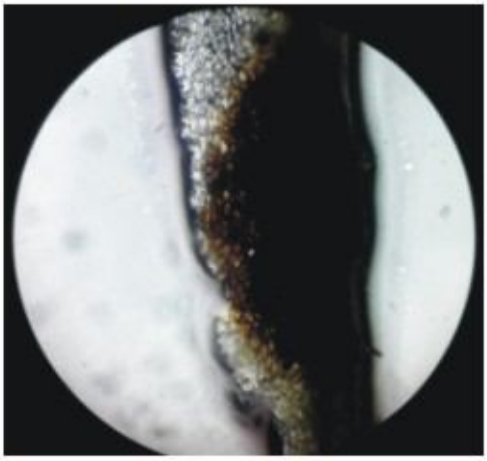




**2b. Hand sectioned leaf showing uredosori and uredospores**

**Plate 2. Microscopic observation of rusted leaf**



3a. Elongated lesions on shoot

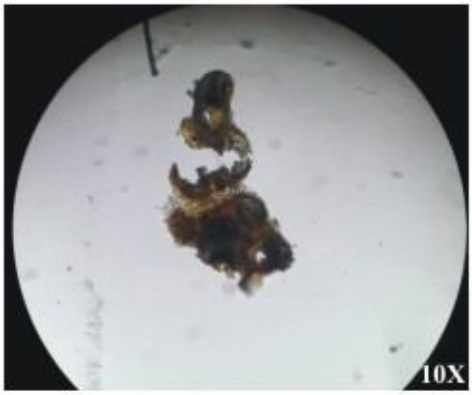


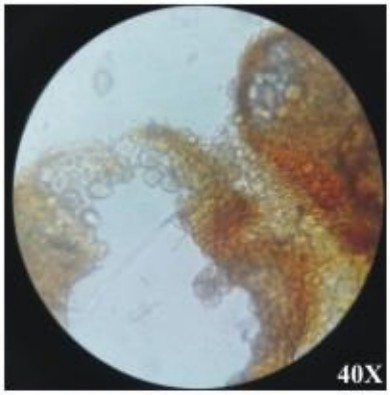
3b. Hand sectioned portion of infected shoot showing no pustule eruption

Plate 3. Symptoms on shoot



4a. Symptoms on fruit




4b. Microscopic view of uredosori and uredospores present on rusted fruit

Plate 4. Symptoms on fruit

### 4.1.2 Spore morphology

The uredospores were appeared as dusty brown on the lower side of the leaf. The spores were found to be oblong to elongated in shape. The spores were echinulated (Plate 5a) and found to have 1-3 germpores from which germtube emerged (Plate 5b & 5c).

## 4.2 Survey for fig rust severity in major fig growing regions of North Karnataka

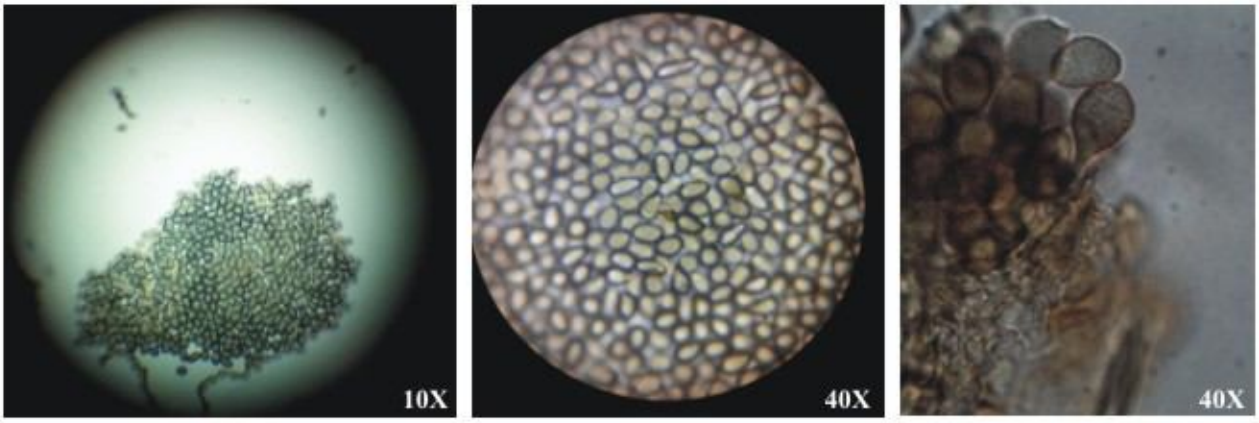
In order to know the severity of rust disease of fig, roving survey was conducted during the year 2017-18, in the areas of Bagalkot, Koppal and Ballary districts of North Karnataka. The observation pertaining to survey is presented in Table 3.

Majority of fig cultivated area is covered by the variety Bellary which is highly susceptible to the disease. On an average, Ballary district recorded the maximum disease severity (66.93 PDI).

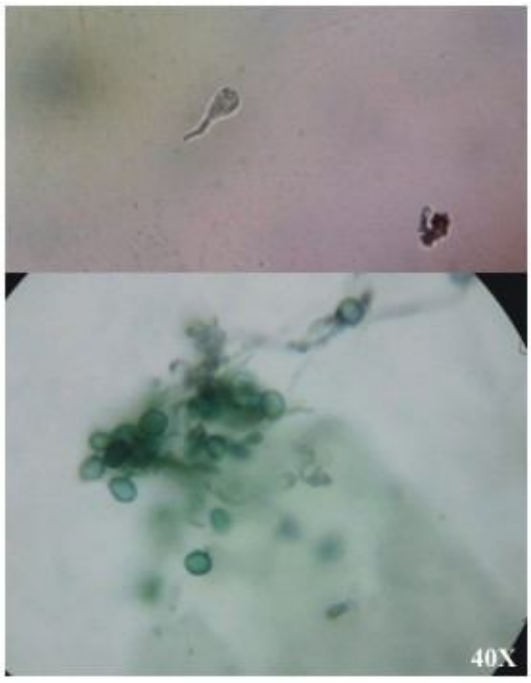
In Bagalkot district four taluks were surveyed *viz.*, Bagalkot, Badami, Bilagi and Hungund. Hungund taluk recorded maximum disease severity (57.78) and least in Bilagi taluk (46.67).

In Ballary district, Ballary taluk recorded maximum PDI (70.79) followed by, Hospet taluk (65.19) and Siraguppa (64.81). In Ballary taluk Sirigere village found to have maximum disease severity (82.22) followed by H Veerapura (73.33) and least severity was observed in Nelludi (51.11). In Hospet taluk, maximum disease severity was observed in Ramasagara (82.22) and least in Nelludi (51.11). In Siraguppa taluk, maximum disease severity was recorded in Kunchageri (82.22), followed by Muddatanur (73.33) and least in Chanavasapura (51.11).

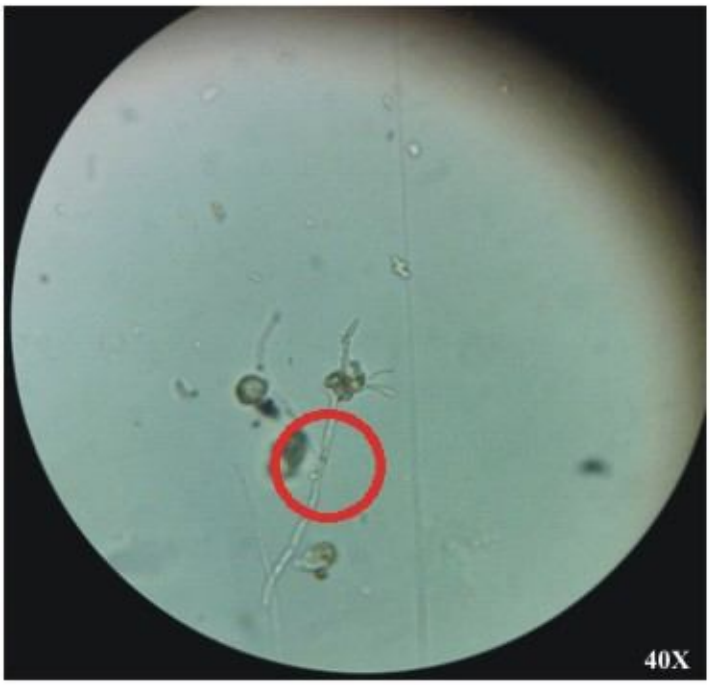
In Koppal district, two taluks were surveyed, in which Koppal taluk recorded maximum disease severity (67.45) followed by Gangavathi taluk (60.74). In Koppal taluk the maximum disease severity was observed in Alwandi and Alavandi villages (82.22) and least in Dombarhalli (20.00). In Gangavathi taluk, maximum PDI was




5a. Echinulation on the urdospore




5b.Germinated uredospore




5c. Three germtubes from a uredospore

Plate 5. *Cerotelium fici* uredospore morphology

**Table 3: Severity of fig rust in major fig growing districts of North Karnataka**

| Sl. No. | District | Taluk | Variety | PDI |
|---|---|---|---|---|
| 1 | **Bagalkot** | **Badami** | | |
| | | Kelur | Bellary | 51.11 |
| | | Mangalagudda | Bellary | 46.67 |
| | | **Mean** | | **48.89** |
| | | **Bagalkot** | | |
| | | Bagalkot | Bellary | 73.33 |
| | | Bevinamatti | Bellary | 19.75 |
| | | Muchakandi | Bellary | 64.44 |
| | | **Mean** | | **52.51** |
| | | **Bilagi** | | |
| | | Anagawadi | Bellary | 51.11 |
| | | Sunaga | Local | 42.22 |
| | | **Mean** | | **46.67** |
| | | **Hungund** | | |
| | | Ammingada | Bellary | 60.00 |
| | | Hungund | Bellary | 55.56 |
| | | **Mean** | | **57.78** |
| | | **District Average** | | **51.46** |
| 2 | **Ballary** | **Ballary** | | |
| | | Ballary | Bellary | 82.22 |
| | | Bairapura | Bellary | 68.89 |
| | | H Veerapura | Bellary | 73.33 |
| | | Kurgodu | Bellary | 64.44 |
| | | Laxminagar camp | Bellary | 64.44 |
| | | Sirigere | Bellary | 82.22 |
| | | Srinivas camp | Bellary | 60.00 |
| | | **Mean** | | **70.79** |
| | | **Hospet** | | |
| | | Bukkasagara | Bellary | 60.00 |
| | | Devsandra | Bellary | 68.89 |
| | | Nelludi | Bellary | 51.11 |
| | | Ramasagara | Bellary | 82.22 |
| | | Sanapura | Bellary | 55.56 |

*Contd.....*

| Sl. No. | District | Taluk | Variety | PDI |
|---|---|---|---|---|
| | | Sitharama Tanda | Bellary | 73.33 |
| | | **Mean** | | **65.19** |
| | | **Siraguppa** | | |
| | | Chanavasapura | Bellary | 51.11 |
| | | Kenchanakoppa | Bellary | 64.44 |
| | | Kunchageri | Bellary | 82.22 |
| | | Muddatanur | Bellary | 73.33 |
| | | Mudenur | Bellary | 57.78 |
| | | Nadivi | Bellary | 60.00 |
| | | **Mean** | | **64.81** |
| | | **District Average** | | **66.93** |
| 3 | **Koppal** | **Gangavathi** | | |
| | | Achalapura | Bellary | 68.89 |
| | | Agoli | Bellary | 55.56 |
| | | Anegundi | Bellary | 60.00 |
| | | Basapattana | Bellary | 55.56 |
| | | Chikkajanthakal | Bellary | 64.44 |
| | | KVK, Gangavathi | Bellary | 60.00 |
| | | **Mean** | | **60.74** |
| | | **Koppal** | | |
| | | Alavandi | Bellary | 82.22 |
| | | Alwandi | Bellary | 77.78 |
| | | Bikanhalli | Bellary | 76.94 |
| | | Dombarhalli | Local | 20.00 |
| | | Hiresindogi | Bellary | 65.56 |
| | | Munirabad | Bellary | 82.22 |
| | | **Mean** | | **67.45** |
| | | **District Average** | | **64.09** |

recorded in Achalapura (68.89) followed by Chikkajanthakal (64.44) and least in Angoli and Basapattana (55.56).

### 4.3 Proving Pathogenicity

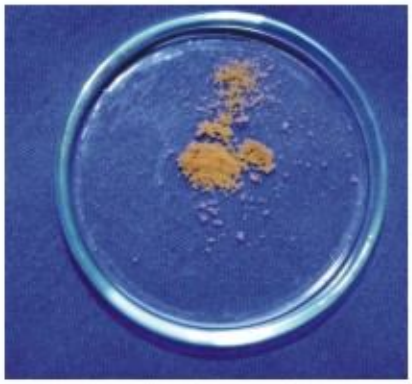
For proving the Koch postulates of pathogenicity for *C. fici* on fig plants, four methods of inoculation *viz.*, dusting, leaf pinning, plaster and spray inoculation were carried out as described in 3.4. All the methods were found effective for the production of disease symptoms (Plate 6). The plants inoculated by spraying found to have more latent period (9 days) when compared with other methods of inoculation (Table 4).

The artificial inoculation was done for the six varieties of fig *viz.*, Bellary, Conadriya, Dienna, Dinakar, Excel and Poona. The varieties Excel and Bellary was found to have less latent period (7 days) when compared with other four varieties (8 days) (Table 4). The observation on pustule formation after ten days of first appearance of symptom showed that spray inoculation was more effective followed by dusting, plaster and leaf pinning method in producing maximum disease. When the data of all the methods of inoculation was averaged variety wise, Dienna recorded maximum disease, followed by Excel, Conadriya, Bellary, Dinakar and least in Poona.

### 4.4 Effect of sugars, relative humidity and temperature on uredospore germination

#### 4.4.1 Effect of sugars on uredospore germination

The uredospore germination was carried out in tap water, RO water, distilled water and the water agar (0.5%) containing sucrose (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0%) and dextrose (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0%). The results presented in the Table 5 and Fig. 1 revealed that the least spore germination was observed in RO water (4.22%), which was on par with distilled water (4.29%) and tap water (4.56%). The sucrose at 2.5 per cent concentration recorded the maximum germination (51.79%) and was found to be significantly superior than other concentrations tested. The sucrose at 2.0 per cent was found next best treatment showing 43.41 per cent spore germination, which was followed by dextrose at 2.0 per cent concentration



Uredospore dust



Dusting on leaf



Lessions on Adaxial surface



Uredosori on abaxial surface

**Plate 6a. Dust method of inoculation**



Uredospore dust



Dusting on leaf

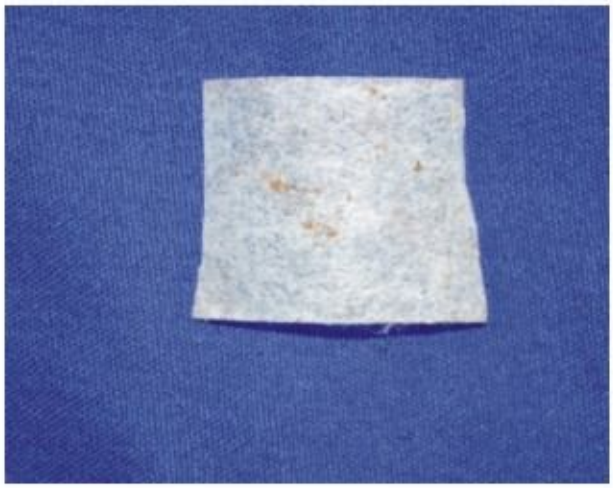


Lessions on Adaxial surface

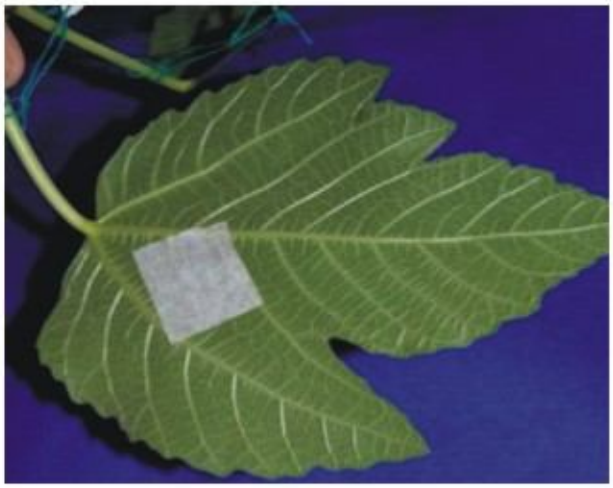


Uredosori on abaxial surface

**Plate 6b. Leaf pinning method of inoculation**



Adhesive tape dusted with spores



Pasting of tape on lower leaf surface



Lessions on Adaxial surface



Uredosori on abaxial surface

**Plate 6c. Plaster method of inoculation**



Spraying of uredospore suspension



Lessions on adaxial surface

**Plate 6d. Spray method of inoculation**




**Plate 6. Proving pathogenicity and diffrent methods of uredospore inoculation**

**Table 4: Effect of different uredospore inoculation techniques on different varieties of fig in inducing disease development**.

| Sl. No. | Variety | Method of inoculation | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Dusting | | Leaf pinning | | Plaster | | Spray | |
| | | No. of pustules | Latent period (days) | No. of pustules | Latent period (days) | No. of pustules | Latent period (days) | No. of pustules | Latent period (days) |
| 1 | Conadriya | 30 | 8 | 10 | 8 | IN | 8 | IN | 9 |
| 2 | Excel | IN | 7 | 15 | 7 | 20 | 7 | IN | 9 |
| 3 | Dienna | IN | 8 | IN | 8 | 28 | 8 | IN | 9 |
| 4 | Dinakar | 1 | 8 | 25 | 8 | 25 | 8 | 24 | 9 |
| 5 | Bellary | 27 | 7 | 25 | 7 | 30 | 7 | IN | 9 |
| 6 | Poona | NO | --- | 4 | 8 | 20 | 8 | IN | 9 |

*IN- innumerable pustules were observed (10-25% area affected)
* NO- no infection

**Table 5: Standardization of different concentrations of sugar solution on uredospore germination of *Cerotelium fici***

| Sl. No. | Treatment details | Sugar conc. (%) | Spore germination (%) |
|---|---|---|---|
| 1 | Tap Water | -- | 4.56 (12.33) |
| 2 | RO water | -- | 4.22 (11.86) |
| 3 | Distilled water | -- | 4.29 (11.95) |
| 4 | Sucrose | 0.5 | 27 (31.30) |
| 5 | Sucrose | 1.0 | 33.98 (35.66) |
| 6 | Sucrose | 1.5 | 38.3 (38.23) |
| 7 | Sucrose | 2.0 | 43.41 (41.21) |
| 8 | Sucrose | 2.5 | 51.79 (46.03) |
| 9 | Sucrose | 3.0 | 42.23 (40.59) |
| 10 | Dextrose | 0.5 | 28.86 (32.49) |
| 11 | Dextrose | 1.0 | 31.94 (34.41) |
| 12 | Dextrose | 1.5 | 35.34 (36.48 ) |
| 13 | Dextrose | 2.0 | 43.05 (41.01) |
| 14 | Dextrose | 2.5 | 39.16 (38.74) |
| 15 | Dextrose | 3.0 | 24.18 (29.45) |
| S.Em± | | | 0.31 |
| CD @ 0.01 | | | 0.90 |

* Values in the parenthesis are arc sine transformed

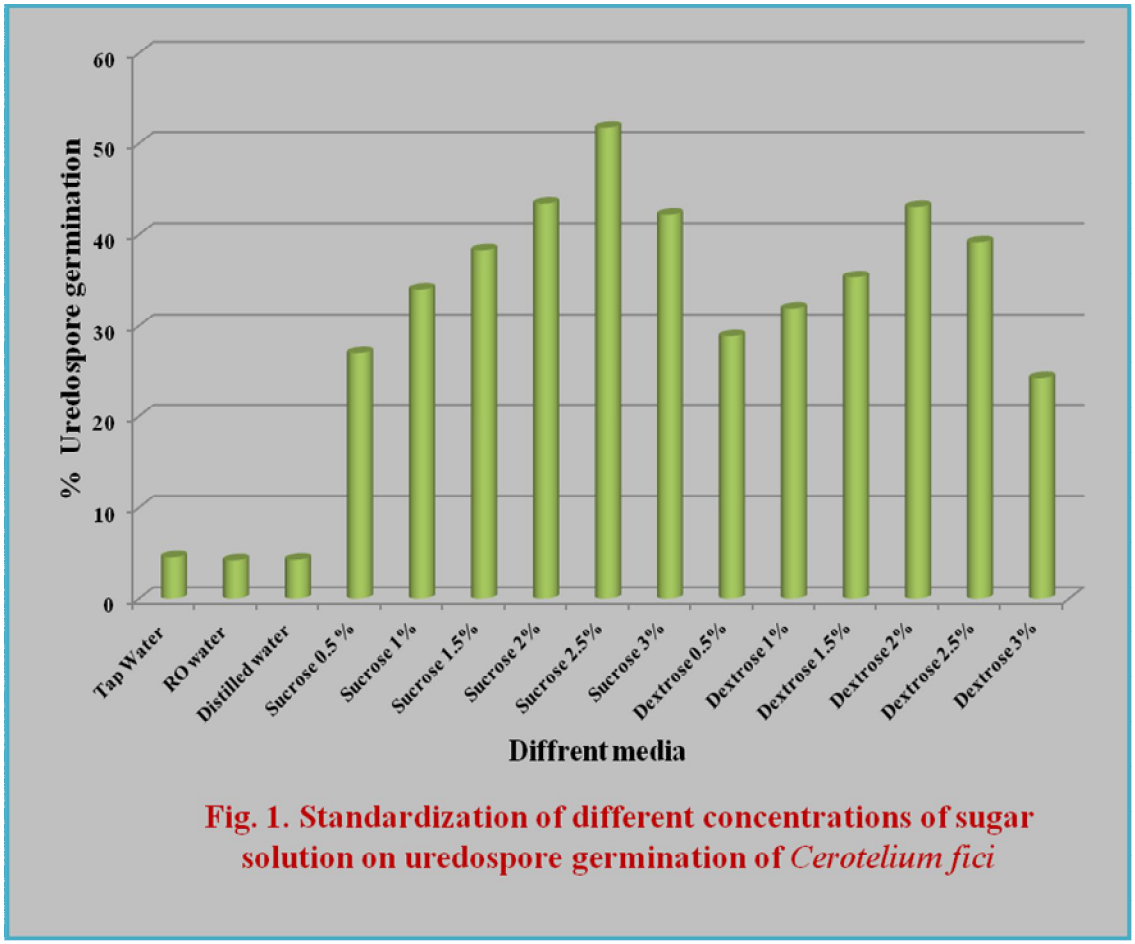



**Fig. 1. Standardization of different concentrations of sugar solution on uredospore germination of *Cerotelium fici***

(43.05%) and sucrose at 3.0 per cent (42.23%). Among the sugar concentrations tested, the dextrose at 3.0 per cent has recorded the least germination (24.18%) followed by sucrose at 0.5 per cent (27.00%) and dextrose at 0.5 per cent concentration (28.86%) and these were found to be significantly different from each other.

### 4.4.2 Effect of temperature on uredospore germination

The uredospore germination studies was conducted at different temperatures from 10 to 40˚ C.The data from the Table 6 revealed that mean maximum spore germination was observed at 25 ˚C (51.10%) and it was significantly superior over 20˚ C (37.34%) and 15˚ C (14.45%) temperature. Amongst all the treatments the least per cent spore germination was recorded at 40 ˚C (1.22%) (Table 6 and Fig. 2).

### 4.4.3 Effect of relative humidity on uredospore germination

The data on the uredospore germination at different relative humidity (%) tested presented in the Table 7 and Fig. 3, which clearly showed that the mean maximum uredospore germination was at 100 per cent relative humidity (60.38%) followed by 95 per cent (49.56%). The least spore germination was recorded at 70 per cent relative humidity (3.54%). At 65 per cent relative humidity uredospore germination was not observed.

## 4.5 Screening of fig varieties

### 4.5.1 Screening of fig varieties for resistance to rust disease in natural epiphytotic condition

Fig genotypes *viz.,* Poona, Bellary, Dinakar, Conadriya, Dienna and Excel were tested for their resistance to rust disease under natural epiphytotic conditions (Plate 7). The data presented in the Table 8 clearly shows that among all the varieties, Excel (56.98 PDI) was severely infected followed by Dienna (55.96 PDI), Bellary (54.68 PDI), Conadriya (52.88 PDI), Dinakar (52.84 PDI) and Poona (47.72 PDI). Therefore, all the varieties were found to be highly susceptible except Poona, which could be called as susceptible.

**Table 6: Effect of temperature on uredospore germination of *Cerotelium fici***

| Sl. No. | Temperature (˚C) | Spore germination (%) |
|---|---|---|
| 1 | 10 | 8.48<br>(16.19) |
| 2 | 15 | 14.45<br>(22.32) |
| 3 | 20 | 37.34<br>(37.65) |
| 4 | 25 | 51.10<br>(45.61) |
| 5 | 30 | 8.27<br>(16.70) |
| 6 | 35 | 6.71<br>(14.95) |
| 7 | 40 | 1.22<br>(6.10) |
| | S. Em± | 0.72 |
| | CD @ 0.01 | 2.21 |

*Values in the paranthesis are arc sine transformed

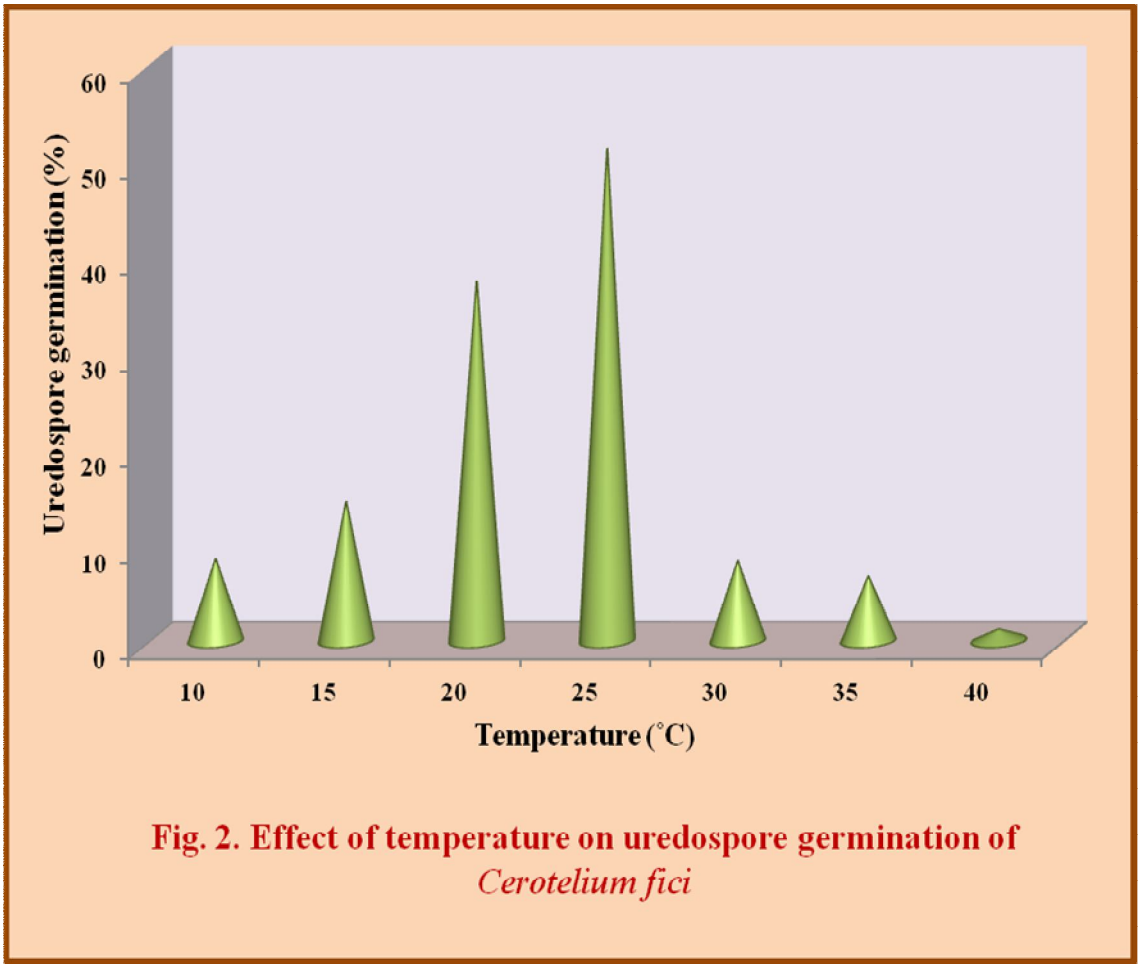



**Fig. 2. Effect of temperature on uredospore germination of *Cerotelium fici***

**Table 7: Effect of relative humidity on uredospore germination of *Cerotelium fici***

| Sl. No. | Relative humidity (%) | Spore germination (%) |
|---|---|---|
| 1 | 65 | 0.00<br>(5.73) |
| 2 | 70 | 3.54<br>(10.83) |
| 3 | 75 | 6.00<br>(14.13) |
| 4 | 80 | 10.16<br>(18.56) |
| 5 | 85 | 22.54<br>(28.32) |
| 6 | 90 | 24.17<br>(29.42) |
| 7 | 95 | 49.56<br>(44.73) |
| 8 | 100 | 60.38<br>(50.96) |
| | S. Em± | 0.47 |
| | CD @ 0.01 | 1.38 |

*Values in the paranthesis are arc sine transformed

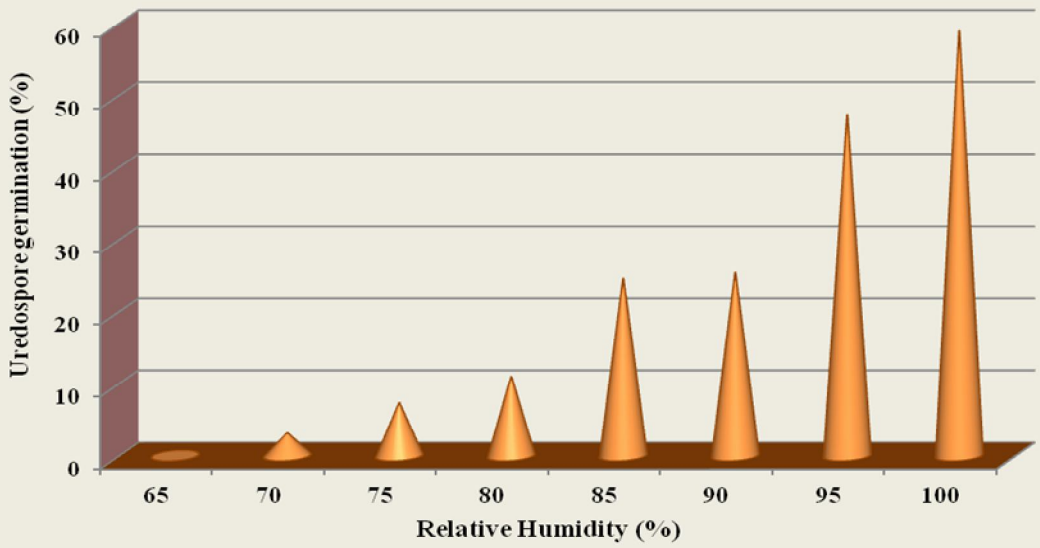



**Fig. 3. Effect of relative humidity on uredospore germination of *Cerotelium fici***




**General field view**



**Leaf tagging for assessing AUDPC and apparent rate of infection**




**Var. Excel**

**Plate 7. Screening of fig varieties**

**Table 8: Screening of fig varieties for resistance to rust disease**

| Sl. No. | Variety | Disease scale | Average PDI | Remarks |
|---|---|---|---|---|
| 1 | Conadriya | 9 | 52.88 | Highly susceptible |
| 2 | Excel | 9 | 56.98 | Highly susceptible |
| 3 | Dienna | 9 | 55.96 | Highly susceptible |
| 4 | Dinakar | 9 | 52.84 | Highly susceptible |
| 5 | Bellary | 9 | 54.68 | Highly susceptible |
| 6 | Poona | 7 | 47.72 | Susceptible |

### 4.5.2 The area under disease progress curve (AUDPC) and apparent rate of infection (r values)

The AUDPC values and apparent rate of infection of rust diseases in six fig varieties is presented in the Table 9. The maximum area under disease progress curve was found in Excel (3207.65), followed by Dienna (3157.99) and Bellary (3155.88). The least AUDPC value was observed in Poona (2005.99) followed by Dinakar (2605.52) and Conadriya (3067.29).

The apparent rate of infection differed among the fig varieties, in which the variety Dienna recorded the maximum average r value (0.089), followed by Dinakar (0.070). The least infection rate was observed in Bellary (0.049). The r value of Bellary was 0.136, 0.027, 0.026 and 0.006 at $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ day after infection respectively. The r value of Conadriya was 0.155, 0.060, 0.023 and 0.003 at $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ day after infection respectively. Dienna recorded the r value of 0.297, 0.050, 0.005 and 0.003 at $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ day after infection respectively. The r value of Dinakar was 0.188, 0.038, 0.027 and 0.029 at $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ day after infection respectively. On the variety Excel, the r value observed was 0.180, 0.048, 0.013 and 0.001 at $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ day after infection respectively. The r value of Poona was 0.130, 0.02, 0.04 and 0.05 at $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ day after infection respectively.

### 4.5.3 Effect of environmental factors on rust development

#### 4.5.3.1 Simple linear correlation and regression analysis

##### 4.5.3.1.1 Simple linear correlation

The observations on disease severity of rust were recorded on fig varieties *viz.*, Conadriya, Excel, Dienna, Dinakar, Bellary and Poona at weekly interval from October, 2017 to May, 2018 and correlated with the weather parameters of the same week, one week prior to the observed data and two weeks prior.

The data presented in the Table 10a revealed that the weather parameter morning RH (%) was significantly positively correlated with disease severity of Bellary (0.470), Conadriya (0.477), Dienna (0.435), Dinakar (0.610), Excel (0.516) and Poona (0.552). The evening RH (%) was positively and significantly correlated

**Table 9: Apparent rate of infection (r) and area under disease progress curve (AUDPC) values of fig rust caused by *C. fici* in different fig varieties**

| Sl. No | Variety | r values | | | | | |
|---|---|---|---|---|---|---|---|
| | | 7 DAI | 14 DAI | 21 DAI | 28 DAI | Average r | AUDPC |
| 1 | Conadriya | 0.155 | 0.060 | 0.023 | 0.003 | 0.060 | 3067.29 |
| 2 | Excel | 0.180 | 0.048 | 0.013 | 0.001 | 0.061 | 3207.65 |
| 3 | Dienna | 0.297 | 0.050 | 0.005 | 0.003 | 0.089 | 3157.99 |
| 4 | Dinakar | 0.188 | 0.038 | 0.027 | 0.029 | 0.070 | 2605.52 |
| 5 | Bellary | 0.136 | 0.027 | 0.026 | 0.006 | 0.049 | 3155.88 |
| 6 | Poona | 0.130 | 0.020 | 0.040 | 0.050 | 0.061 | 2005.99 |

DAI- Days After Initial infection

**Table 10a: Correlation co-efficient between meteorological factors and rust disease in different fig varieties**

| Sl. No. | Weather parameters | r values | | | | | |
|---|---|---|---|---|---|---|---|
| | | Conadriya | Excel | Dienna | Dinakar | Bellary | Poona |
| 1 | Relative humidity (am) % | 0.477** | 0.516** | 0.435* | 0.610** | 0.470** | 0.552** |
| 2 | Relative humidity (pm) % | 0.488** | 0.538** | 0.491** | 0.496** | 0.425* | 0.611** |
| 3 | Temperature (Min) ˚C | -0.806** | -0.798** | -0.684** | -0.522** | -0.003 | -0.395* |
| 4 | Temperature (Max) ˚C | -0.875** | -0.885** | -0.753** | -0.738** | -0.253 | -0.656** |
| 5 | Rainfall (mm) | -0.018 | -0.254 | -0.256 | -0.064 | -0.076 | -0.040 |

** Significance at 0.01 (r=0.456); *Significance at 0.05 (r=0.355)

with rust disease in Bellary (0.425), Conadriya (0.488), Dienna (0.491), Dinakar (0.496), Excel (0.538) and Poona (0.611). The minimum temperature was negatively significantly correlated with disease in Conadriya (-0.806), Dienna (-0.684), Dinakar (-0.522), Excel (-0.798) and Poona (-0.395) and non significantly negatively correlated with disease in Bellary (-0.003). Maximum temperature was significantly negatively correlated with Conadriya (-0.875), Dienna (-0.753), Dinakar (-0.738), Excel (-0.885) and Poona (-0.656) and non significantly negatively correlated with Bellary (-0.253). The rainfall has no significant correlation with disease severity and was negatively correlated with all the varieties.

To know the relation of the weather parameters on the disease severity of preceding week, correlation studies were conducted and the data is presented in Table 10b. The disease severity of Bellary was significantly positively correlated with morning RH (0.438) and afternoon RH (0.388), non significantly positively correlated with minimum temperature (0.015) and non significantly negatively correlated with maximum temperature (-0.250) and non significantly positively correlated with rainfall (0.267). The disease severity in variety Conadriya showed significant positive correlation with morning RH (0.583) and afternoon RH (0.535), significant negative correlation with minimum temperature (-0.695) and maximum temperature (-0.794) and non significantly positively correlated with rainfall (0.075). The rust disease in Dienna showed significant positive correlation with morning RH (0.440) and afternoon RH (0.540), significant negative correlation with minimum temperature (-0.609) and maximum temperature (-0.741) and non significantly negatively correlated with rainfall (-0.131). The disease on Dinakar variety showed significant positive correlation with morning RH (0.545), afternoon RH (0.484), significant negative correlation with minimum temperature (-0.383) and maximum temperature (-0.637) and non significant positive correlation with rainfall (0.021). In Excel the disease showed significant positive correlation with morning RH (0.604), afternoon RH (0.548), significant negative correlation with minimum temperature (-0.628), maximum temperature (-0.841) and non significantly negatively correlated with rainfall (-0.033). The disease severity in the variety Poona was significantly positively

**Table 10b: Correlation co-efficient between one week prior meteorological factors and rust disease in different fig varieties**

| Sl. No. | Weather parameters | r values | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Conadriya** | **Excel** | **Dienna** | **Dinakar** | **Bellary** | **Poona** |
| 1 | Relative humidity (am) % | 0.583** | 0.604** | 0.440* | 0.545** | 0.438* | 0.505** |
| 2 | Relative humidity (pm) % | 0.535** | 0.548** | 0.540** | 0.484** | 0.388* | 0.678** |
| 3 | Temperature (Min) ˚C | -0.695** | -0.628** | -0.609** | -0.383* | 0.015 | -0.269 |
| 4 | Temperature (Max) ˚C | -0.794** | -0.841** | -0.741** | -0.637** | -0.250 | -0.605** |
| 5 | Rainfall (mm) | 0.075 | -0.033 | -0.131 | 0.0.21 | 0.267 | 0.068 |

** Significance at 0.01 (r=0.456); *Significance at 0.05 (r=0.355)

correlated with morning RH (0.505) and afternoon RH (0.678), non significantly negatively correlated with minimum temperature (-0.269), significantly negatively correlated with maximum temperature (-0.605) and non significantly positively correlated with rainfall (0.068).

The results presented in the Table 10c shows the relationship between the weather parameters prevailing two weeks before the observed disease severity. The data revealed that morning and afternoon relative humidity were significantly positively correlated with disease severity of Conadriya (0.625, 0.565), Dienna (0.526, 0.519), Dinakar (0.590, 0.491), Excel (0.628, 0.546), Poona (0.550, 0.692) except for Bellary in which the disease showed significant positive correlation with morning RH (0.410) and non significant positive correlation with afternoon RH (0.297). The minimum and maximum temperature were significantly negatively correlated with rust disease in Conadriya (-0.535, -0.837), Dienna (-0.533, -0.750), Dinakar (-0.320, -0.620), Excel (-0.563, -0.788) and Poona (-0.180, -0.541) showed non significant negative correlation with minimum temperature and significant negative correlation with maximum temperature. In Bellary the disease showed non significant positive correlation with minimum temperature (0.016) and non significant negative correlation with maximum temperature (-0.233). The rainfall was non significantly positively correlated with Bellary (0.248), Dienna (0.039), Dinakar (0.110), Excel (0.106) and Poona (0.184) and was negatively correlated with Conadriya (-0.009).

It is evident from the Table 10a, 10b and 10c that relative humidity has positive influence on the disease and the temperature has negative. The rainfall has no significant correlation with the disease severity.

#### 4.5.3.1.2 Regression analysis

The occurrence and growth of rust disease depends on several weather parameters. Therefore to know the influence of meteorological parameters on rust disease severity regression analysis was conducted.

**Table 10c: Correlation co-efficient between two week prior meteorological factors and rust disease in different fig varieties**

| Sl. No. | Weather parameters | r values | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Conadriya** | **Excel** | **Dienna** | **Dinakar** | **Bellary** | **Poona** |
| 1 | Relative humidity (am) % | 0.625** | 0.628** | 0.526** | 0.590** | 0.410* | 0.550** |
| 2 | Relative humidity (pm) % | 0.565** | 0.546** | 0.519** | 0.491** | 0.297 | 0.692** |
| 3 | Temperature (Min) ˚C | -0.535** | -0.563** | -0.533** | -0.320 | 0.016 | -0.180 |
| 4 | Temperature (Max) ˚C | -0.837** | -0.788** | -0.750** | -0.620** | -0.233 | -0.541** |
| 5 | Rainfall (mm) | -0.009 | 0.106 | 0.039 | 0.110 | 0.248 | 0.184 |

** Significance at 0.01 (r=0.456); *Significance at 0.05 (r=0.355)

**The regression equation for fig rust severity determined from the weather factors of the same week**.

Regression equation for Bellary was Y=46.33 + 0.21 MRH + 0.05ARH + 1.35$T_{min}$ -1.19$T_{max}$ - 1.01RF, Conadriya was Y=126.08 + 0.26MRH - 0.11ARH - 0.46$T_{min}$ - 2.31 $T_{max}$ -1.37RF, Excel was Y=130.73 + 0.22 MRH - 0.06ARH - 0.62 $T_{min}$ - 2.24 $T_{max}$ - 0.53RF, Dienna was Y= 104.78 + 0.18MRH - 0.01ARH - 0.70$T_{min}$ - 1.41$T_{max}$ + 0.71RF, Dinakar was Y=103.80 + 0.08MRH - 0.06ARH - 0.57$T_{min}$ - 2.07$T_{max}$ + 0.79RF and Poona was Y=90.60 + 0.07 MRH + 0.02 ARH + 1.09 $T_{min}$ - 2.25 $T_{max}$ - 0.13RF. Here MRH depicts the morning relative humidity (%), ARH, afternoon relative humidity (%), $T_{min}$ was minimum temperature (˚C), $T_{max}$ was maximum temperature (˚C) and RF is Rainfall (mm). The relative contribution of each weather factor to the disease severity (Y) could be predicted from the above equation and the influence of these factors differed among the varieties.

The co-efficient of determinative value ($R^2$) was found to be indicating that 32 per cent on Bellary, 82 per cent on Conadriya, 58 per cent on Dienna, 67 per cent on Dinakar, 81 per cent on Excel and 56 per cent on Poona of variation in disease severity was accounted by linear function (Table 11).

**Regression equations for fig rust severity determined by weather factors prevailing one week prior**

The regression equation for Bellary was Y= 30.86 + 0.14 MRH + 0.12 ARH + 0.03 $T_{min}$ + 0.16 $T_{max}$ + 1.32RF, $R^2$ value of which was indicating 24 per cent variation in disease severity was ascribed to the linear function. The regression equation for Conadriya was Y=103.12 + 0.19 MRH + 0.02 ARH - 1.74 $T_{min}$ - 0.90 $T_{max}$ + 2.76RF, which shows that morning and afternoon relative humidity and rainfall are having positive influence whereas minimum and maximum temperature were having negative influence. These factors were accountable to the extent of 83 per cent. Regression equation of Dienna was Y=102.41 + 0.41 MRH + 0.04 ARH - 0.91 $T_{min}$ - 1.22 $T_{max}$ - 0.54RF, 61 per cent of variation in disease severity was attributed to this linear function. Regression equation of Dinakar was Y= 61.05 + 0.18 MRH + 0.0002 ARH - 0.19 $T_{min}$ - 0.54 $T_{max}$ - 0.58RF this owed 47 per cent variation in disease severity.

**Table 11: Regression equation for rust severity in six varieties of fig in relation to weather parameters**

| Week | Variety | Regression equation | $R^2$ value |
|---|---|---|---|
| $W_1$ | Conadriya | Y=126.08 + 0.26 MRH - 0.11 ARH -0.46 $T_{min}$ - 2.31 $T_{max}$ - 1.37 RF | 0.82 |
| | Excel | Y=130.73 + 0.22 MRH - 0.06 ARH - 0.62 $T_{min}$ - 2.24 $T_{max}$ - 0.53 RF | 0.81 |
| | Dienna | Y= 104.78 + 0.18 MRH - 0.01 ARH -0.70 $T_{min}$ - 1.41 $T_{max}$ + 0.71 RF | 0.58 |
| | Dinakar | Y=103.80 + 0.08 MRH - 0.06 ARH - 0.57 $T_{min}$ - 2.07 $T_{max}$+ 0.79 RF | 0.67 |
| | Bellary | Y=46.33 + 0.21 MRH + 0.05 ARH + 1.35 $T_{min}$ - 1.19 $T_{max}$ - 1.01 RF | 0.32 |
| | Poona | Y=90.60 + 0.07 MRH + 0.02 ARH + 1.09 $T_{min}$ - 2.25 $T_{max}$ - 0.13 RF | 0.56 |
| $W_2$ | Conadriya | Y=103.12 + 0.19 MRH + 0.02 ARH - 1.74 $T_{min}$ - 0.90 $T_{max}$ + 2.76 RF | 0.83 |
| | Excel | Y=104.30 + 0.35 MRH - 0.04 ARH - 0.98 $T_{min}$ - 1.5 $T_{max}$ - 0.62 RF | 0.79 |
| | Dienna | Y=102.41 + 0.41 MRH + 0.04 ARH - 0.91 $T_{min}$ - 1.22 $T_{max}$ - 0.54 RF | 0.61 |
| | Dinakar | Y=61.05 + 0.18 MRH + 0.0002 ARH - 0.19 $T_{min}$ - 0.54 $T_{max}$ - 0.58 RF | 0.47 |
| | Bellary | Y=30.86 + 0.14 MRH + 0.12 ARH + 0.03 $T_{min}$ + 0.16 $T_{max}$ + 1.32 RF | 0.24 |
| | Poona | Y=55.85 + 0.012 MRH + 0.15 ARH + 0.04 $T_{min}$ - 0.60 $T_{max}$ + 0.62 RF | 0.51 |
| $W_3$ | Conadriya | Y=93.10 + 0.39 MRH - 0.05 ARH - 0.29 $T_{min}$ - 1.83 $T_{max}$ + 0.79 RF | 0.79 |
| | Excel | Y=87.01 + 0.41 MRH - 0.03 ARH - 1.06 $T_{min}$ - 1.13 $T_{max}$ - 0.58 RF | 0.73 |
| | Dienna | Y=96.04 + 0.28 MRH - 0.01 ARH - 0.77 $T_{min}$ - 1.34 $T_{max}$ + 0.69 RF | 0.62 |
| | Dinakar | Y=54.15 + 0.22 MRH + 0.002 ARH - 0.18 $T_{min}$ - 0.44 $T_{max}$ - 0.51 RF | 0.48 |
| | Bellary | Y=30.31 + 0.20 MRH + 0.04 ARH + 0.05 $T_{min}$+ 0.13 $T_{max}$+ 0.21 RF | 0.17 |
| | Poona | Y=35.37 + 0.10 MRH + 0.17 ARH + 0.063 $T_{min}$ - 0.19 $T_{max}$ + 0.51 RF | 0.51 |

$W_1$ – Same week at seven days interval
$W_2$ – One week prior to the observed disease severity
$W_3$ – Two week prior to the observed disease severity
Y- Per cent disease index (PDI)
MRH- Morning relative humidity (%)
ARH- Afternoon relative humidity (%)
$T_{min}$- Minimum temperature (˚C)
$T_{max}$- Maximum temperature (˚C)
RF- Rainfall (mm)

Regression equation of Excel was Y=104.30 + 0.35 MRH - 0.04ARH - 0.98 $T_{min}$ - 1.5 $T_{max}$ - 0.62RF and Poona was Y=55.85 + 0.012 MRH + 0.15 ARH + 0.04 $T_{min}$ - 0.60 $T_{max}$ + 0.62RF, $R^2$ value of which was indicating that 73 per cent and 51 per cent of variation in disease severity was accounted to linear function respectively.

**Regression equations for fig rust severity determined by weather factors prevailing two weeks prior**

Regression equation for Bellary was Y=30.31 + 0.20 mRH + 0.04 MRH + 0.05 $T_{min}$+ 0.13 $T_{max}$+ 0.21RF, Conadriya was Y=93.10 + 0.39 mRH - 0.05 MRH - 0.29 $T_{min}$ - 1.83 $T_{max}$ + 0.79RF, Dienna was Y=96.04 + 0.28mRH - 0.01 MRH - 0.77 $T_{min}$ - 1.34 $T_{max}$ + 0.69RF, Dinakar was Y=54.15 + 0.22 mRH + 0.002MRH - 0.18 $T_{min}$ - 0.44 $T_{max}$ - 0.51RF, Excel was Y=87.01 + 0.41 mRH - 0.03 MRH - 1.06 $T_{min}$ - 1.13 $T_{max}$ - 0.58RF and Poona was Y=35.37 + 0.10 mRH + 0.17 MRH + 0.063 $T_{min}$ - 0.19 $T_{max}$ + 0.51RF.

The co-efficient of determinative was found to be 17 per cent on Bellary, 79 per cent on Conadriya, 62 per cent on Dienna, 48 per cent on Dinakar, 73 per cent on Excel and 51 per cent on Poona (Table 11).

### 4.5.4 Biochemical studies

#### 4.5.4.1 Reducing sugars

**Upper leaves**

The results of reducing sugar content analysed at monthly intervals is presented in the Table 12. The quantity of reducing sugars of upper leaves varied among the varieties and also between the healthy and rust affected plants (Table 12a and Fig. 4a).

In the month of November, 2017 in the upper leaves of healthy plant the least reducing sugar content was recorded in Dinakar (15.14 mg/g) which was significantly different. The highest reducing sugar content was recorded in Dienna (16.44 mg/g) which was on par with Poona (16.33 mg/g), Bellary (15.49 mg/g), Conadriya (15.49 mg/g) and Excel (15.37 mg/g). In the rust affected plants the highest reducing sugar

**Table 12a. Reducing sugar content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Reducing sugar content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 15.49 | 16.92 | 15.16 | 14.66 | 16.92 | 16.53 | HS |
| 2 | Excel | 15.37 | 26.47 | 15.17 | 16.13 | 20.12 | 23.93 | HS |
| 3 | Dienna | 16.44 | 16.45 | 14.80 | 14.63 | 19.46 | 15.06 | HS |
| 4 | Dinakar | 15.14 | 15.61 | 18.61 | 14.87 | 14.70 | 17.28 | HS |
| 5 | Bellary | 15.49 | 22.37 | 15.50 | 16.18 | 17.31 | 22.90 | HS |
| 6 | Poona | 16.33 | 25.80 | 14.43 | 16.96 | 16.88 | 23.37 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.41 | 1.29 | 0.01 | 0.03 | 0.01 | 0.04 | |
| | Sample | 0.24 | 0.74 | 0.01 | 0.02 | 0.01 | 0.03 | |
| | V× S | 0.59 | 1.82 | 0.01 | 0.04 | 0.02 | 0.06 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible

**Table 12b. Reducing sugar content in the lower leaves of healthy and rust infected fig varieties at monthly interval**

| Sl. No. | Variety | Reducing sugar content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 20.74 | 17.88 | 19.91 | 15.63 | 18.87 | 21.63 | HS |
| 2 | Excel | 14.53 | 19.26 | 22.38 | 23.88 | 16.75 | 19.81 | HS |
| 3 | Dienna | 22.83 | 23.01 | 19.87 | 22.61 | 19.60 | 20.84 | HS |
| 4 | Dinakar | 23.37 | 24.32 | 22.43 | 24.23 | 22.81 | 25.63 | HS |
| 5 | Bellary | 22.53 | 27.05 | 20.74 | 22.72 | 25.59 | 27.97 | HS |
| 6 | Poona | 18.95 | 20.68 | 15.86 | 18.45 | 16.30 | 26.68 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.40 | 1.26 | 0.17 | 0.53 | 0.23 | 0.72 | |
| | Sample | 0.23 | 0.73 | 0.10 | 0.31 | 0.13 | 0.42 | |
| | V× S | 0.57 | 1.78 | 0.24 | 0.76 | 0.33 | 1.02 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible

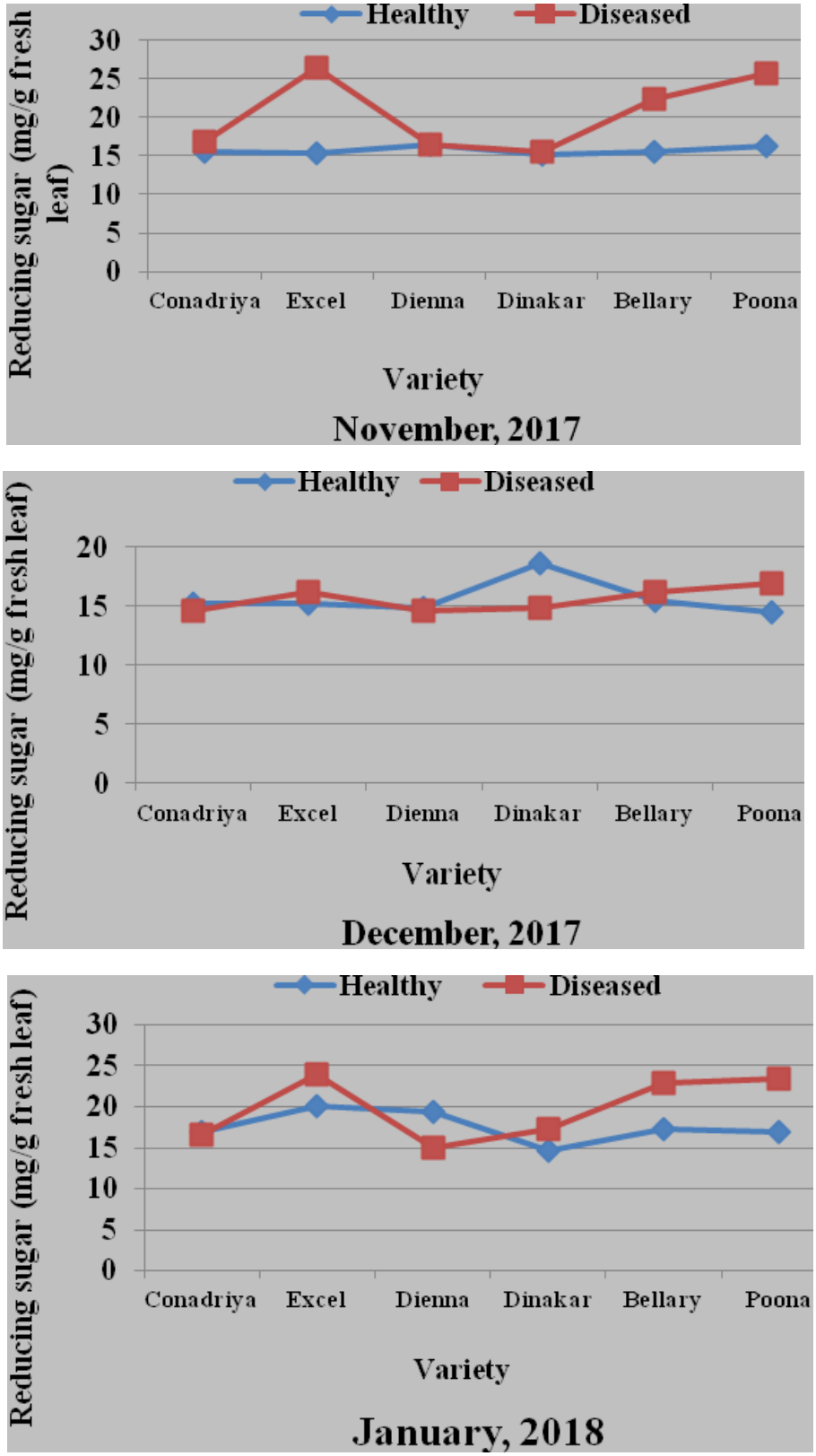



**Fig. 4a. Reducing sugar content in the upper leaves of healthy and diseased fig varieties**

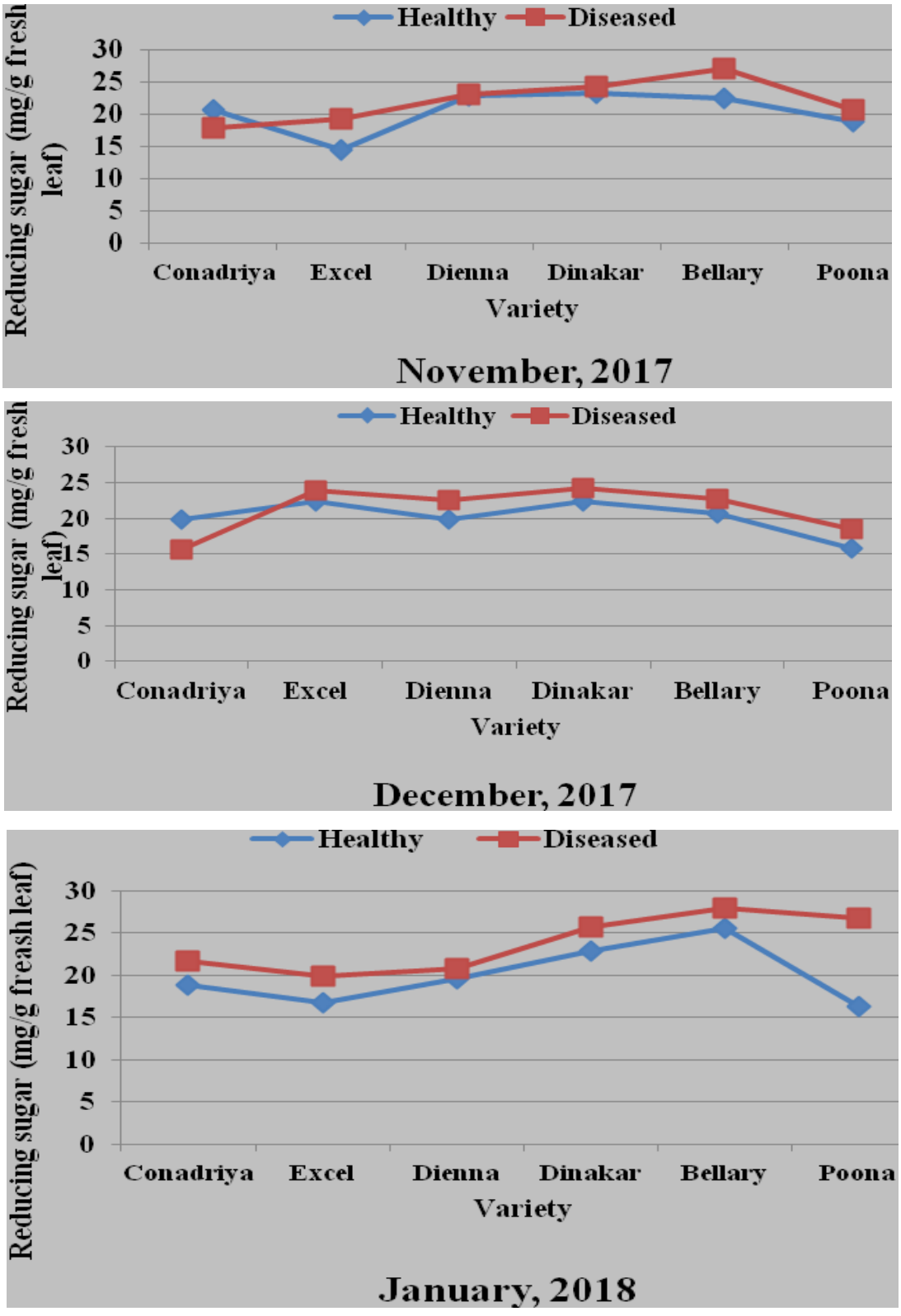



**Fig. 4b. Reducing sugar content in the lower leaves of healthy and diseased fig varieties**

content was recorded in Excel (26.47 mg/g) which was on par with Poona (25.80 mg/g). The lowest reducing sugar content was recorded in Dinakar (15.61 mg/g), followed by Conadriya (16.92 mg/g) and significantly different from each other.

In the month of December, 2017 the reducing sugars recorded was different from the previous month. The data in the table shows that the highest reducing sugar content in the upper leaf of healthy plant was recorded in Dinakar (18.61 mg/g) followed by Bellary (15.50 mg/g) and were statistically significant. The least reducing sugar content was found in Poona (14.43 mg/g), followed by Dienna (14.80 mg/g). Variety Poona (16.96 mg/g) had highest reducing sugar content, followed by Bellary (16.18 mg/g) and Excel (16.13 mg/g) and was significantly different from each other. The least sugar content was recorded in Dienna (14.63 mg/g) and was on par with Conadriya (14.66 mg/g).

The estimation of reducing sugars in January, 2018 showed that variety Excel (20.12 mg/g) had more sugars and was significantly superior over other varieties, followed by Dienna (19.46 mg/g) and Bellary (17.31 mg/g). The least sugar content was observed in Dinakar (14.70 mg/g), followed by Poona (16.88 mg/g) which was on par with Conadriya (16.92 mg/g). In the rust affected fig plants the upper leaf of Excel (23.93 mg/g) recorded maximum sugars, followed by Poona (23.37 mg/g) and Bellary (22.90 mg/g). The Dienna (15.06 mg/g) recorded least sugar content, followed by Conadriya (16.53 mg/g) and Dinakar (17.28 mg/g) and were found to be statistically significant.

**Lower leaves**

The reducing sugars content in the lower leaves of healthy and rust affected plants are presented in the Table 12b and Fig. 4b.

The results revealed that in the month of November, 2017, the healthy leaves recorded the highest reducing sugars in Dinakar (23.37 mg/g) which was on par with Dienna (22.83 mg/g) and Bellary (22.53 mg/g). The lowest reducing sugar content was observed in Excel (14.53 mg/g). In the rust affected plants, the highest reducing sugar content was recorded in Bellary (27.05 mg/g), followed by Dinakar (24.32 mg/g) and Dienna (23.01 mg/g). The least sugar content was recorded in Conadriya (17.88 mg/g), followed by Excel (19.26 mg/g).

In the December, 2017, the reducing sugar concentration recorded was different from the previous month. The data in the Table 12b shows that the highest reducing sugar content in the healthy plant was recorded in Dinakar (22.43 mg/g) and was on par with Excel (22.38 mg/g). The least reducing sugar content was found in Poona (15.86 mg/g), followed by Dienna (19.87 mg/g) which was on par with Conadriya (19.91 mg/g). In case of diseased plant the variety Dinakar (24.23 mg/g) had highest reducing sugar content and was on par with Excel (23.88 mg/g). The least sugar content was recorded in Conadriya (15.63 mg/g), followed by Poona (18.45 mg/g) and Dienna (22.61 mg/g) which was on par with Bellary (22.72 mg/g).

In the month of January, 2018, the variety Bellary (25.59 mg/g) had more reducing sugars and was significantly superior over other varieties, followed by Dinakar (22.81 mg/g) and Dienna (19.60 mg/g). The least sugar content was observed in Poona (16.30 mg/g), followed by Excel (16.75 mg/g) which were on par with each other. In the rust infected plants, Bellary (27.97 mg/g) recorded maximum sugars, followed by Poona (26.68 mg/g) and Dinakar (25.63 mg/g). The Excel (19.81 mg/g) recorded least reducing sugar content, followed by Dienna (20.84 mg/g) and Conadriya (21.63 mg/g).

#### 4.5.4.2 Total sugars

**Upper leaves**

The results of total sugar content analysed at monthly intervals is presented in the Table 13 and Fig. 5a. The total sugar content in upper leaves varied among the varieties and also between the healthy and rust affected plants.

In the upper leaves of healthy plant, the highest total sugar content was recorded in Conadriya (27.70 mg/g) which was significantly superior, followed by Dinakar (26.07 mg/g) and Poona (25.79 mg/g). The least sugar content was observed in Bellary (19.61 mg/g) followed by Dienna (22.85 mg/g) and were statistically different from each other.

However, the total sugar content in the upper leaves of rust affected fig plants showed a different pattern with respect to varieties. The variety Poona (35.83 mg/g) which is susceptible to the rust disease recorded maximum sugar content which was

significantly superior over other varieties which were highly susceptible. The Excel (32.62 mg/g) and Bellary (25.56 mg/g) were next to Poona. The least sugar content was observed in Dienna (19.51 mg/g), succeeding Dinakar (22.41 mg/g).

In the December, 2017 the total sugars recorded was different from the previous month. The data in the Table 13a shows that the highest sugar content in the upper leaf of healthy plant was recorded in Excel (28.19 mg/g) followed by Conadriya (26.89 mg/g) and were statistically significant. The total sugar content of Dinakar (24.59 mg/g), Poona (24.43 mg/g) and Bellary (24.25 mg/g) were on par with each other. The least sugar content was found in Dienna (19.51 mg/g). The total sugar content of diseased plant is presented in Table 13, shows that the variety Excel (29.08 mg/g) had highest sugar content, followed by Poona (25.52 mg/g) and Conadriya (24.39 mg/g). The least sugar content was recorded in Bellary (22.77 mg/g) and was on par with Dienna (22.78 mg/g), followed by Dinakar (23.26 mg/g).

The estimation of total sugars in January, 2018 showed that, Conadriya (27.85 mg/g) had more sugars and was significantly superior over other varieties, followed by Excel (26.86 mg/g) and Poona (25.23 mg/g). The least sugar content was observed in Dinakar (22.80 mg/g) and was on par with Dienna (22.83 mg/g). In rust affected fig plants, the upper leaf of Poona (35.09 mg/g) recorded maximum sugars, followed by Excel (33.19 mg/g) and Bellary (25.49 mg/g). The Conadriya (20.38 mg/g) recorded least sugar content, followed by Dienna (20.49 mg/g) and Dinakar (22.81 mg/g).

**Lower leaves**

The sugar content of the upper and lower leaves was varied. The total sugars of the lower leaves of healthy and rust affected plants are presented in the Table 13b and Fig. 5b.

The results revealed that in the month of November, 2017 in the lower leaves of healthy plants, the highest total sugars was recorded in Conadriya (34.21 mg/g), followed by Poona (30.79 mg/g) and Bellary (30.37 mg/g). The lowest total sugar content was observed in Dienna (25.66 mg/g), followed by Dinakar (28.75 mg/g) and Excel (29.97 mg/g). In the rust affected plants, the highest total sugar content was recorded in Excel (35.41 mg/g), followed by Conadriya (34.77 mg/g) and Poona

**Table 13a. Total sugar content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

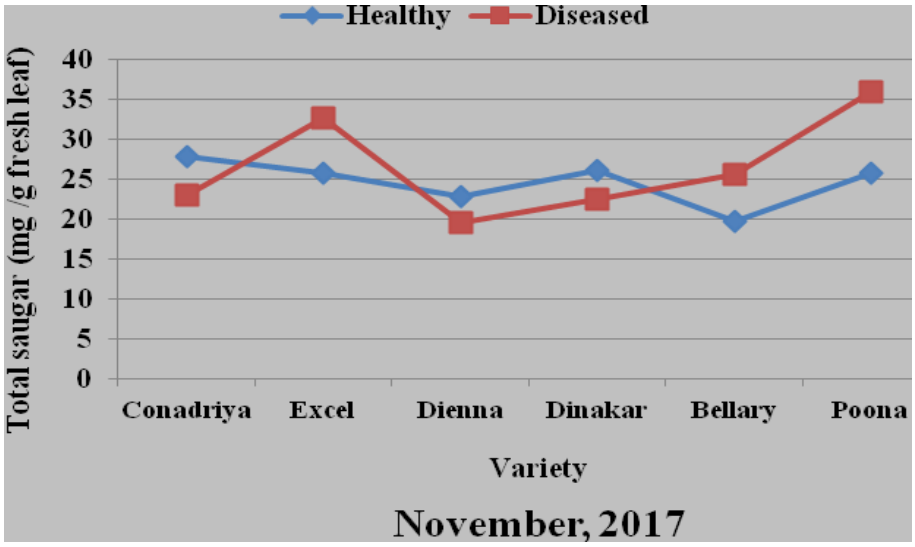
| Sl. No. | Variety | Total sugar content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 27.70 | 22.98 | 26.89 | 24.39 | 27.85 | 20.38 | HS |
| 2 | Excel | 25.71 | 32.62 | 28.19 | 29.08 | 26.86 | 33.19 | HS |
| 3 | Dienna | 22.85 | 19.51 | 21.32 | 22.78 | 22.83 | 20.49 | HS |
| 4 | Dinakar | 26.07 | 22.41 | 24.59 | 23.26 | 22.80 | 22.81 | HS |
| 5 | Bellary | 19.61 | 25.56 | 24.25 | 22.77 | 23.06 | 25.49 | HS |
| 6 | Poona | 25.79 | 35.83 | 24.43 | 25.52 | 25.23 | 35.09 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.08 | 0.26 | 0.09 | 0.27 | 0.04 | 0.12 | |
| | Sample | 0.05 | 0.15 | 0.05 | 0.16 | 0.02 | 0.07 | |
| | V× S | 0.12 | 0.36 | 0.12 | 0.38 | 0.06 | 0.17 | |

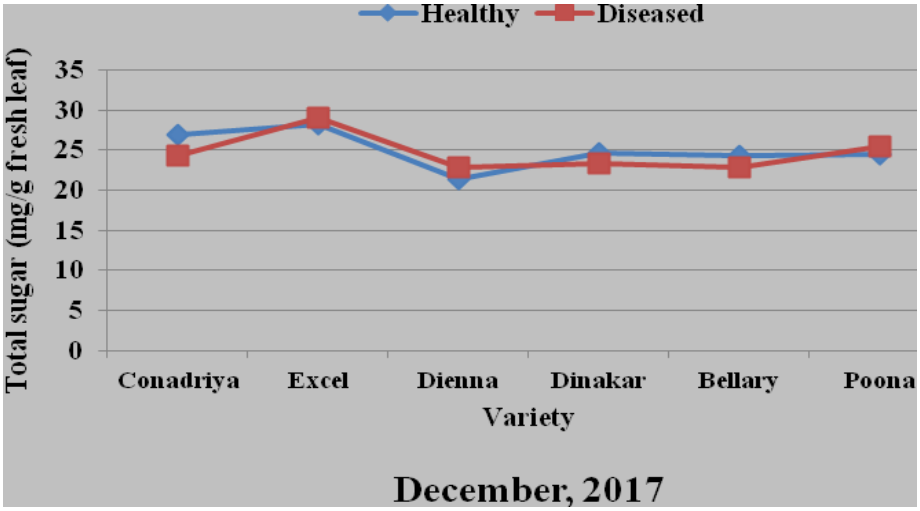
*Significance at 0.01
HS – Highly susceptible; S - Susceptible

**Table 13b. Total sugar content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Total sugar content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 34.21 | 34.77 | 31.27 | 34.77 | 33.04 | 35.32 | HS |
| 2 | Excel | 29.97 | 35.41 | 32.78 | 35.41 | 31.61 | 35.46 | HS |
| 3 | Dienna | 25.66 | 25.56 | 23.29 | 25.56 | 26.11 | 27.55 | HS |
| 4 | Dinakar | 28.75 | 32.60 | 27.49 | 32.60 | 28.62 | 34.26 | HS |
| 5 | Bellary | 30.37 | 33.59 | 29.30 | 33.59 | 33.79 | 35.33 | HS |
| 6 | Poona | 30.79 | 34.59 | 27.65 | 34.59 | 23.62 | 35.09 | S |
| | | S. Em± | CD* | S. Em± | CD* | S. Em± | CD* | |
| | Variety | 0.06 | 0.2 | 0.08 | 0.24 | 0.02 | 0.07 | |
| | Sample | 0.03 | 0.1 | 0.04 | 0.14 | 0.01 | 0.04 | |
| | V× S | 0.08 | 0.3 | 0.11 | 0.33 | 0.03 | 0.10 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible



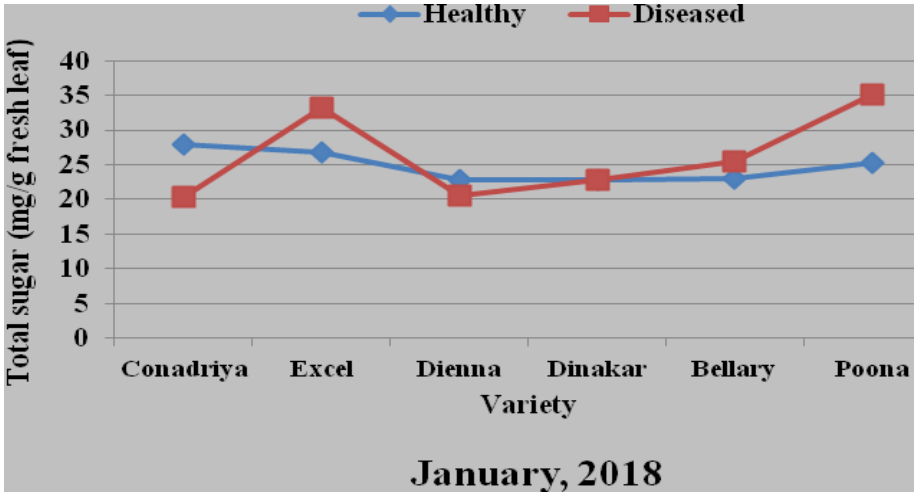




**Fig. 5a. Total sugar content in the upper leaves of healthy and diseased fig varieties**

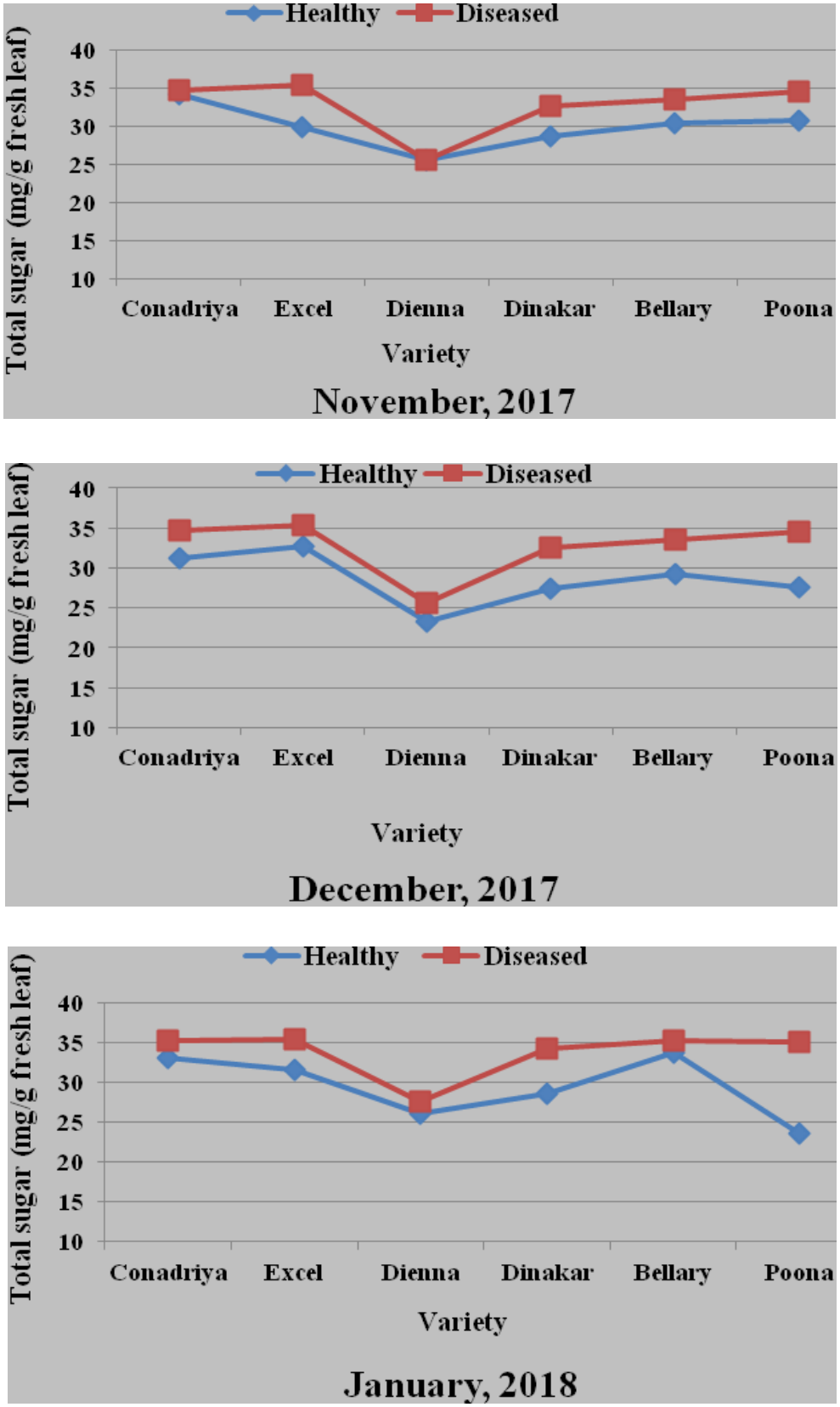



**Fig. 5b. Total sugar content in the lower leaves of healthy and diseased fig varieties**

(34.59 mg/g). The least sugar content was recorded in Dienna (25.56 mg/g). The total sugar content varied significantly.

During the month of December, 2017, the highest sugar content in the lower leaf of healthy plant was recorded in Excel (32.78 mg/g) followed by Conadriya (31.27 mg/g) and Bellary (29.30 mg/g) and were statistically significant. The least sugar content was found in Dienna (23.29 mg/g), followed by Dinakar (27.49 mg/g) which was on par with Poona (27.65 mg/g). The total sugar content in the lower leaves of diseased plant is presented in Table 13b shows that the variety Excel (35.41 mg/g) had highest sugar content found to be statistically superior over other varieties, followed by Conadriya (34..77 mg/g). The least sugar content was recorded in Dienna (25.56 mg/g), followed by Dinakar (32.60 mg/g) and are significantly different from each other.

The estimation of total sugars in January, 2018 showed that variety Bellary (33.79 mg/g) had more sugars and is significantly superior over other varieties, followed by Conadriya (33.04 mg/g) and Excel (31.61 mg/g). The least sugar content was observed in Poona (23.62 mg/g), followed by Dienna (26.11 mg/g) and Dinakar (28.62 mg/g) and were statistically significant. In the rust affected fig plants the lower leaf of Excel (35.46 mg/g) recorded maximum sugars, followed by Bellary (35.33 mg/g), which was on par with Conadriya (35.32 mg/g). The Dienna (27.55 mg/g) recorded least sugar content, followed by Dinakar (34.26 mg/g) and Poona (35.09 mg/g) and were statistically significant.

#### 4.5.4.3 Non reducing sugars

**Upper leaves**

The non reducing sugars estimated in the upper and lower leaves of the healthy and rust infected fig varieties are presented in the Table 14 and Fig. 6a.

The Table 14a, shows the non reducing sugar content of upper leaves of healthy and rust affected plants at monthly intervals. In November, 2017, among the healthy plants Conadriya (12.21 mg/g) recorded maximum non reducing sugar content which was significantly superior, followed by Dinakar (10.93 mg/g) which was on par with Excel (10.34 mg/g). The least non reducing sugar content was

**Table 14a. Non reducing sugar content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Non-reducing sugar content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 12.21 | 6.06 | 12.24 | 9.24 | 10.93 | 3.85 | HS |
| 2 | Excel | 10.34 | 6.15 | 13.03 | 12.95 | 6.75 | 9.27 | HS |
| 3 | Dienna | 6.41 | 3.07 | 8.15 | 6.52 | 3.37 | 5.43 | HS |
| 4 | Dinakar | 10.93 | 6.80 | 5.98 | 8.39 | 8.10 | 5.54 | HS |
| 5 | Bellary | 4.12 | 3.20 | 8.75 | 6.09 | 5.76 | 2.59 | HS |
| 6 | Poona | 9.47 | 10.03 | 10.00 | 9.95 | 8.37 | 11.72 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.45 | 1.40 | 0.05 | 0.15 | 0.18 | 0.55 | |
| | Sample | 0.26 | 0.81 | 0.03 | 0.09 | 0.10 | 0.32 | |
| | V× S | 0.63 | 1.97 | 0.07 | 0.22 | 0.25 | 0.78 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible

**Table 14b. Non reducing sugar content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Non-reducing sugar content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 16.90 | 13.47 | 11.36 | 15.38 | 14.17 | 14.19 | HS |
| 2 | Excel | 15.44 | 14.66 | 9.40 | 9.40 | 14.86 | 15.65 | HS |
| 3 | Dienna | 2.83 | 2.55 | 3.42 | 5.35 | 6.51 | 6.71 | HS |
| 4 | Dinakar | 5.39 | 8.28 | 5.06 | 6.54 | 5.82 | 8.63 | HS |
| 5 | Bellary | 7.84 | 6.54 | 8.56 | 9.50 | 7.20 | 7.36 | HS |
| 6 | Poona | 11.84 | 12.91 | 11.79 | 12.59 | 7.32 | 8.41 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.05 | 0.16 | 0.03 | 0.10 | 0.08 | 0.26 | |
| | Sample | 0.03 | 0.09 | 0.02 | 0.06 | 0.05 | 0.15 | |
| | V× S | 0.07 | 0.23 | 0.05 | 0.14 | 0.12 | 0.37 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible

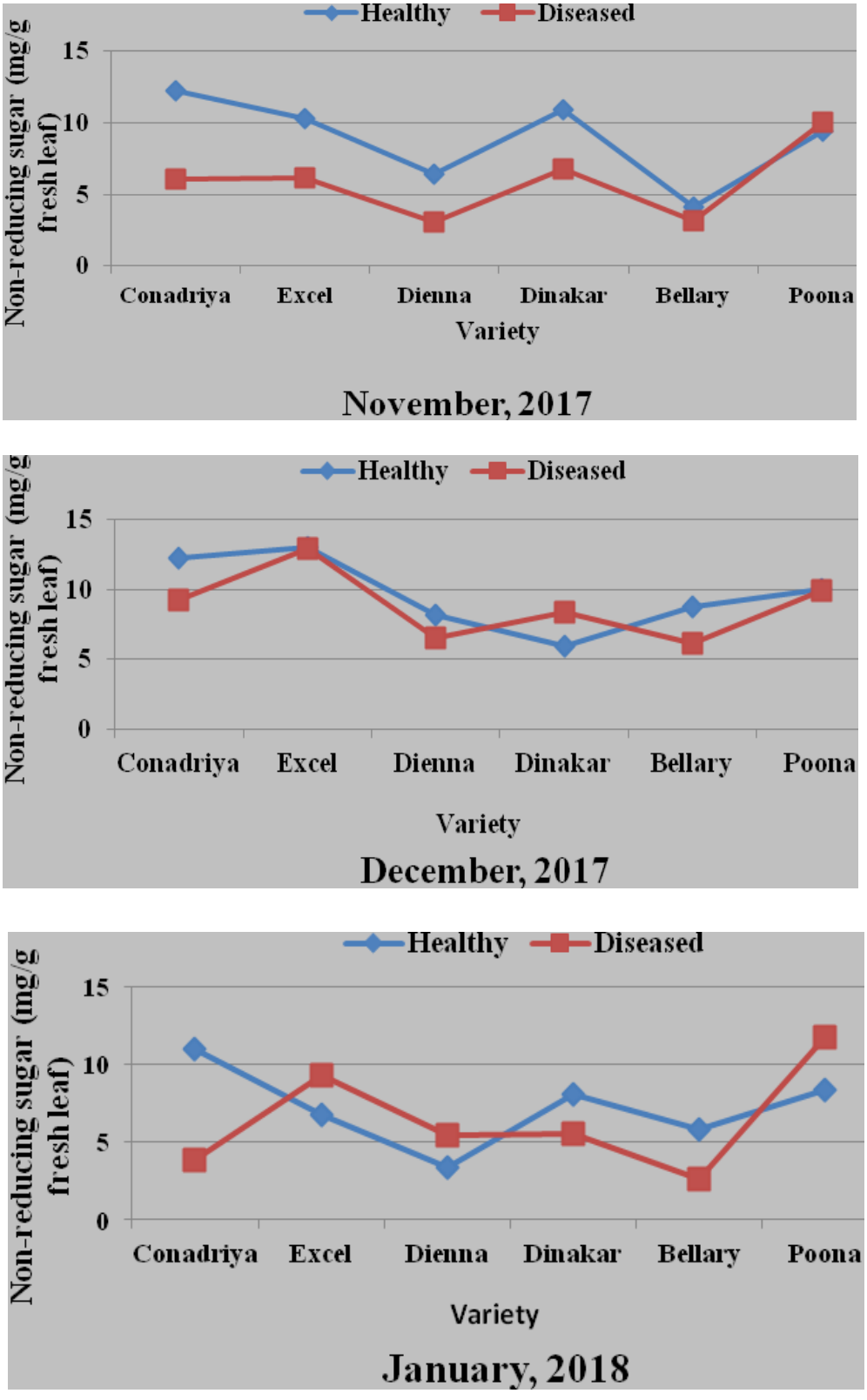



**Fig. 6a. Non- reducing sugar content in the upper leaves of healthy and diseased fig varieties**

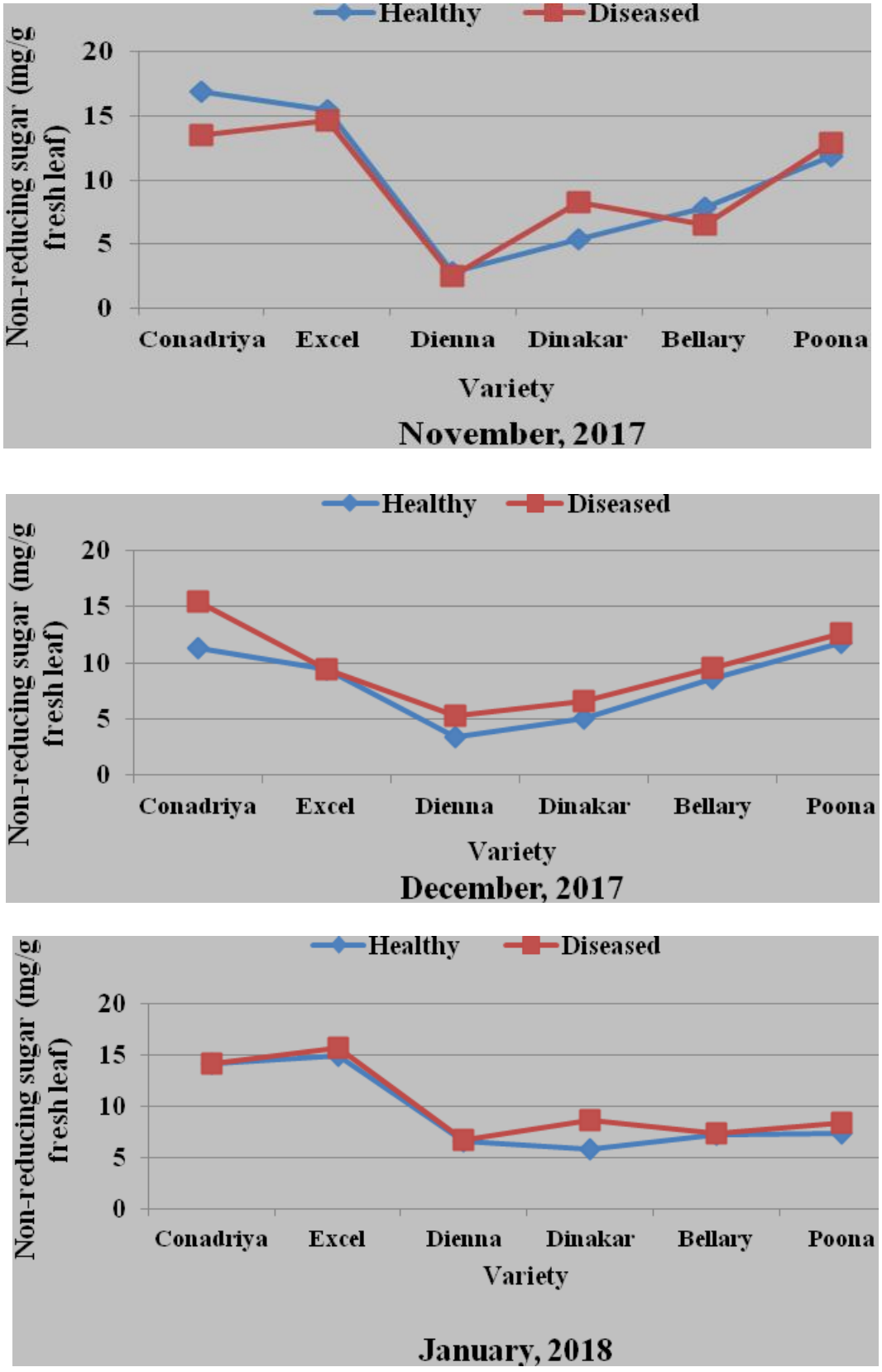



**Fig. 6b. Non- reducing sugar content in the lower leaves of healthy and diseased fig varieties**

observed in Bellary (4.12 mg/g), followed by Dienna (6.41 mg/g) and Poona (9.47 mg/g) and were significantly different from each other. In the rust infected plant the highest non reducing sugar content was observed in Poona (10.03 mg/g), followed by Dinakar (6.80 mg/g) which was on par with Excel (6.15 mg/g) and Conadriya (6.06 mg/g). The least non reducing sugar was observed in Dienna (3.07 mg/g) which was on par with Bellary (3.20 mg/g).

In December, 2017 in the healthy plant, the highest non reducing sugar content was observed in Excel (13.03 mg/g), followed by Conadriya (12.24 mg/g) and Poona (10.00 mg/g). The least non reducing sugar was recorded in Dinakar (5.98mg/g). Non reducing sugars in the upper leaf of diseased plant was maximum in Excel (12.95 mg/g) which was significantly superior, followed by Poona (9.95 mg/g) and Conadriya (9.24 mg/g). The least non reducing sugar content was recorded in Bellary (6.09 mg/g), followed by Dienna (6.52 mg/g). The non reducing sugars varied significantly between all the varieties.

The data presented in the Table 14a revealed that in January, 2018, the healthy plant with highest non reducing sugar content was Conadriya (10.93 mg/g), followed by Poona (8.37 mg/g) which is on par with Dinakar (8.10 mg/g). The least non reducing sugar content was observed in Dienna (3.37 mg/g), followed by Bellary (5.76 mg/g) and Excel (6.75 mg/g) which are significantly different from each other. The data on non reducing sugar content in diseased plant reveals that Poona (11.72 mg/g) had maximum non reducing sugars which was superior over other varieties followed by Excel (9.27 mg/g) and Dinakar (5.54 mg/g) which was on par with Dienna (5.43 mg/g). The lowest non reducing sugar content was observed in Bellary (2.59 mg/g) followed by Conadriya (3.85 mg/g).

**Lower leaves**

The non reducing sugars estimated in the lower leaves of the healthy and rust diseases infected fig varieties are presented in the Table 14b and Fig. 6b.

In November, 2017 among the healthy plants in the lower leaves, the maximum non reducing sugars was recorded in Conadriya (16.90 mg/g), followed by Excel (15.44 mg/g) and Poona (11.84 mg/g). The least non reducing sugar content was observed in Dienna (2.83 mg/g), followed by Dinakar (5.39 mg/g) and Bellary

(7.84 mg/g) and are significantly different from each other. In the rust infected plant, the highest non reducing sugar content was observed in Excel (14.66 mg/g), followed by Conadriya (13.47 mg/g) and Poona (12.91 mg/g) which were significantly superior other varieties. The least non reducing sugar was observed in Dienna (2.55 mg/g). The non reducing sugar content differed significantly.

In December, 2017 in the healthy plant, the highest non reducing sugar content in the lower leaf was observed in Poona (11.79 mg/g) and was significantly superior, followed by Conadriya (11.36 mg/g) and Excel (9.40 mg/g). The least non reducing sugar was recorded in Dienna (3.42 mg/g), followed by Dinakar (5.06 mg/g) and Bellary (8.56 mg/g). Non reducing sugars of the diseased lower leaf was maximum in Conadriya (15.38 mg/g), followed by Poona (12.59 mg/g) and Bellary (9.50 mg/g), which was on par with Excel (9.40 mg/g). The least non reducing sugar content was recorded in Dienna (5.35 mg/g), followed by Dinakar (6.54 mg/g) and differed significantly.

Whereas in the month of January, 2018, in the healthy condition, the lower leaf of the variety Excel (14.86 mg/g) recorded maximum non reducing sugars and was significantly superior, followed by Conadriya (14.17 mg/g). The Poona (7.32 mg/g) was on par with Bellary (7.20 mg/g) in the quantity of non reducing sugars estimated. The least amount of non reducing sugars was recorded in Dinakar (5.82 mg/g), followed by Dienna (6.51 mg/g). In diseased plants, the maximum non reducing sugars was recorded in Excel (15.65 mg/g) followed by Conadriya (14.19 mg/g). The least non reducing sugar content was recorded in Dienna (6.71 mg/g) followed by Bellary (7.36 mg/g) and Poona (8.41 mg/g). The non reducing sugars varied significantly among all the varieties studied.

#### 4.5.4.4 Total Proteins

The total proteins were estimated using Lowry's method and the data obtained is presented in the Table 15 and Fig. 7a.

**Upper leaves**

The Table 15a, shows the protein content of upper leaves of healthy and rust affected plants at monthly intervals. In November, 2017 among the healthy plants, Dienna (85.19 mg/g) recorded maximum protein content and found to be significantly

**Table 15a. Protein content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

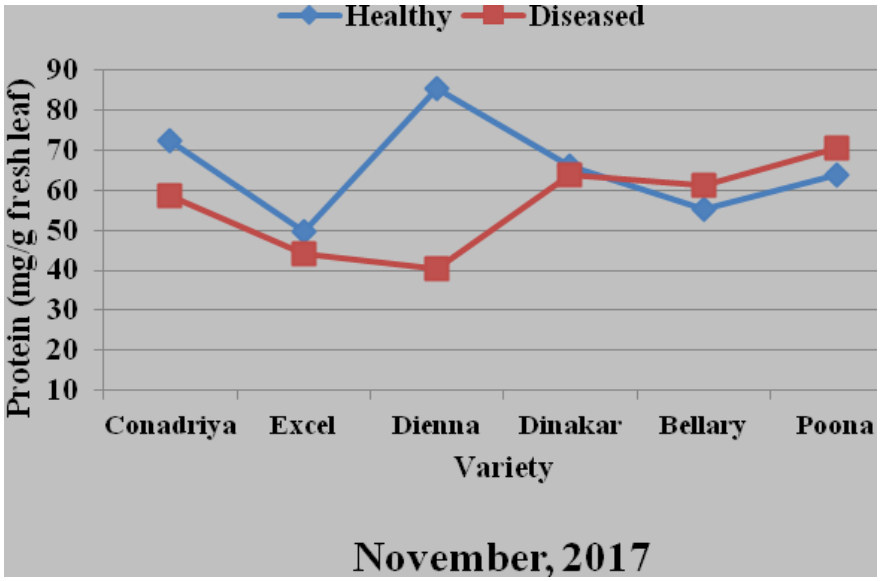
| Sl. No. | Variety | Protein content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 72.33 | 58.69 | 55.80 | 54.19 | 55.25 | 49.14 | HS |
| 2 | Excel | 49.69 | 44.02 | 48.58 | 52.41 | 55.97 | 70.71 | HS |
| 3 | Dienna | 85.19 | 40.36 | 65.83 | 57.41 | 51.19 | 63.03 | HS |
| 4 | Dinakar | 66.17 | 63.72 | 42.47 | 65.69 | 41.86 | 79.55 | HS |
| 5 | Bellary | 55.19 | 61.28 | 55.64 | 53.66 | 46.44 | 88.75 | HS |
| 6 | Poona | 63.77 | 70.41 | 46.86 | 69.56 | 60.25 | 63.61 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 1.66 | 5.17 | 0.67 | 2.09 | 1.01 | 3.13 | |
| | Sample | 0.96 | 2.98 | 0.39 | 1.21 | 0.58 | 1.81 | |
| | V× S | 2.35 | 7.31 | 0.95 | 2.96 | 1.42 | 4.43 | |

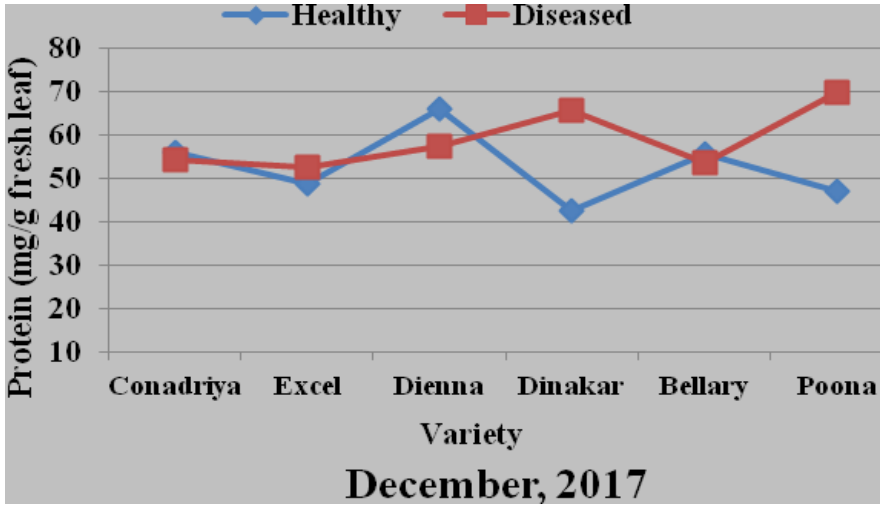
*Significance at 0.01
HS – Highly susceptible; S - Susceptible

**Table 15b. Protein content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Protein content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 47.28 | 47.02 | 38.89 | 46.36 | 48.05 | 94.05 | HS |
| 2 | Excel | 47.92 | 49.39 | 33.20 | 40.89 | 51.16 | 66.55 | HS |
| 3 | Dienna | 35.72 | 48.81 | 46.16 | 50.58 | 39.64 | 69.17 | HS |
| 4 | Dinakar | 36.57 | 48.77 | 34.66 | 40.75 | 40.58 | 57.25 | HS |
| 5 | Bellary | 41.05 | 46.75 | 37.14 | 40.72 | 26.64 | 88.50 | HS |
| 6 | Poona | 44.44 | 58.72 | 30.19 | 49.78 | 37.33 | 55.00 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 1.25 | 2.75 | 0.30 | 0.95 | 0.59 | 1.83 | |
| | Sample | 0.51 | 1.59 | 0.18 | 0.58 | 0.34 | 1.06 | |
| | V× S | 1.25 | 3.89 | 0.43 | 1.34 | 0.83 | 2.58 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible



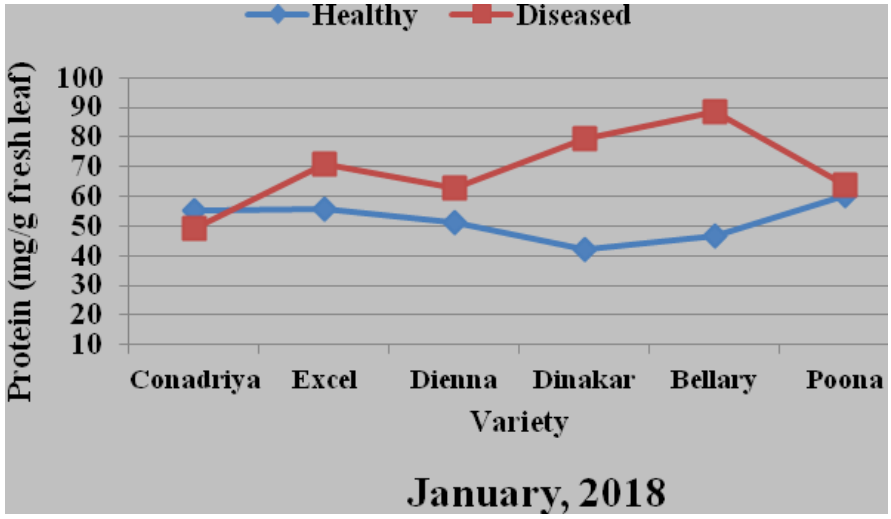
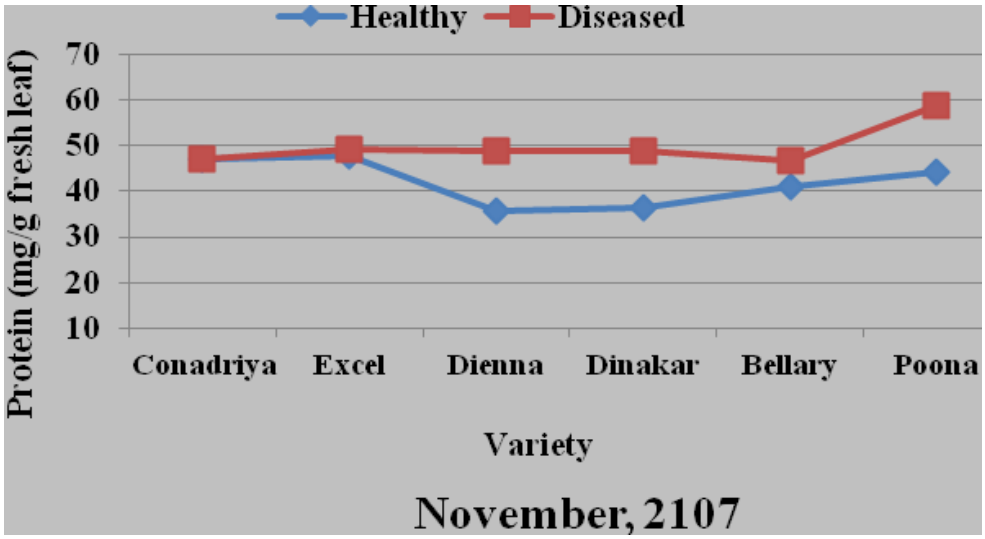
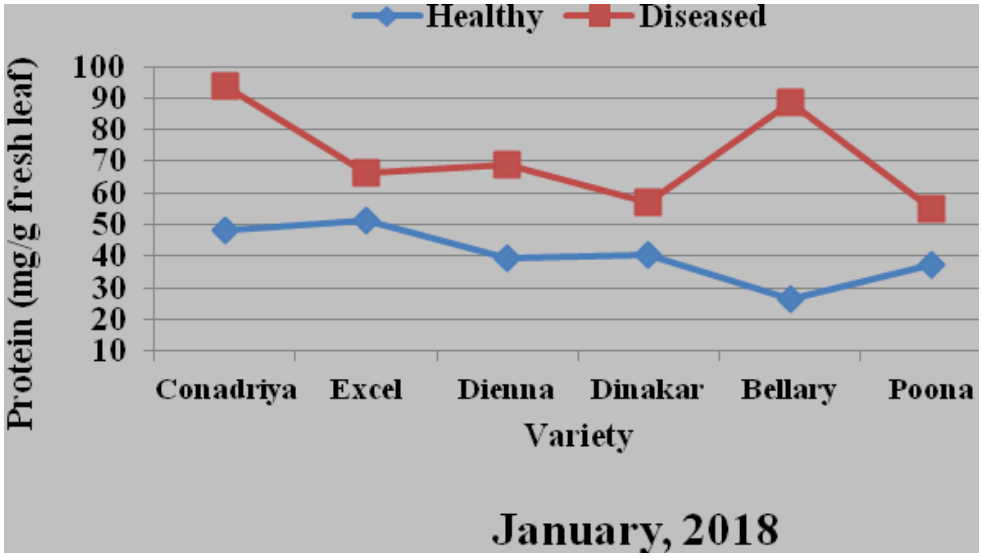




**Fig. 7a. Protein content in the upper leaves of healthy and diseased fig varieties**



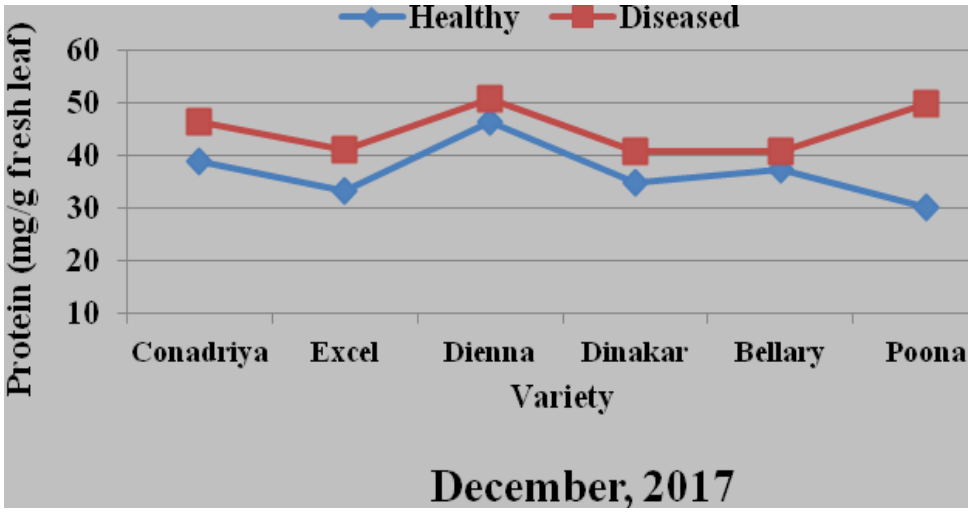




**Fig. 7b. Protein content in the lower leaves of healthy and diseased fig varieties**

superior, followed by Conadriya (72.33 mg/g) and Dinakar (66.17 mg/g). The least protein content was observed in Excel (49.69 mg/g), followed by Bellary (55.19 mg/g) and Poona (63.77 mg/g) and were significantly different from each other. In the rust infected plants, the highest protein content was observed in Poona (70.41 mg/g) and was significantly superior, followed by Dinakar (63.72 mg/g) and Bellary (61.28 mg/g) which were on par with each other. The least protein content was observed in Dienna (40.36 mg/g) which was on par with Excel (44.02 mg/g) followed by Conadriya (58.69 mg/g).

In December, 2017 in the healthy plant, the highest protein content was observed in Dienna (65.83 mg/g), followed by Conadriya (55.80 mg/g) which was on par with Bellary (55.64 mg/g). The least protein content was recorded in Dinakar (42.47 mg/g), followed by Poona (46.86 mg/g) which was on par with Excel (48.58 mg/g). The protein content of the diseased upper leaf was maximum in Poona (69.56 mg/g) and was significantly superior to the other varieties followed by Dinakar (65.69 mg/g) and Dienna (57.41 mg/g). The least protein content was recorded in Excel (52.41 mg/g) which was on par with Bellary (53.66 mg/g) and Conadriya (54.19 mg/g).

In the month of January, 2018, the healthy plant with highest protein content in the upper leaf was Poona (60.25 mg/g), followed by Excel (55.97 mg/g) which was on par with Conadriya (55.25 mg/g). The least protein content was observed in Dinakar (41.86 mg/g), followed by Bellary (46.44 mg/g) and Dienna (51.19 mg/g) which were significantly different from each other. The data on protein content in diseased plant revealed that Bellary (88.75 mg/g) recorded maximum protein content followed by Dinakar (79.55 mg/g) and Excel (70.71 mg/g) and significantly different from each other. The least protein content was observed in Conadriya (49.14 mg/g) followed by Dienna (63.03 mg/g) which was on par with Poona (63.61 mg/g).

**Lower leaves**

The protein content of lower leaves of healthy and rust affected plants at monthly intervals is depicted in Table 15b and Fig. 7b.

In the month of November, 2017 among the healthy plants of different varieties highest protein content was observed in Excel (47.92 mg/g) which was on

par with Conadriya (47.28 mg/g). The least protein content was observed in Dienna (35.72 mg/g) which was on par with Dinakar (36.57 mg/g). In the rust infected plants, the highest protein content was observed in Poona (58.72 mg/g) which was significantly different from other varieties. The protein content of Excel (49.39 mg/g), Dienna (48.81 mg/g), Dinakar (48.77 mg/g), Conadriya (47.02 mg/g) and Bellary (46.75 mg/g) were on par with each other.

In December, 2017, the highest protein content in the lower leaf of the healthy plants among the different varieties was observed in Dienna (46.16 mg/g), followed by Conadriya (38.89 mg/g) and Bellary (37.14 mg/g). The least protein content was recorded in Poona (30.19 mg/g) followed by Excel (33.20 mg/g) and Dinakar (34.66 mg/g). The protein content differed significantly from each other. Whereas in the diseased plant, the highest protein content was observed in Dienna (50.58 mg/g) which was highly susceptible to the rust disease and it was on par with a susceptible variety, Poona (49.78 mg/g). The least protein content was observed in Bellary (40.72 mg/g) which was on par with Dinakar (40.75 mg/g) and Excel (40.89 mg/g).

The data in the Table 15b clearly revealed that in the healthy plants, the lower leaf of Excel (51.16 mg/g) recorded highest protein content, followed by Conadriya (48.05 mg/g) and Dinakar (40.58 mg/g) and was found to be significantly different from each other. The variety Bellary (26.64 mg/g) recorded the least protein content, followed by Poona (37.33 mg/g) and Dienna (39.64 mg/g) and statistically significant. However in the diseased plant the lower leaf of Conadriya (94.05 mg/g) recorded highest protein content which was superior over other varieties followed by Bellary (88.50 mg/g) and Dienna (69.17 mg/g). The least protein content was observed in Poona (55.00 mg/g), followed by Dinakar (57.25 mg/g) and Excel (66.55 mg/g). The protein content observed was significantly different.

#### 4.5.4.5 Total Phenols

**Upper leaves**

The total phenols observed in the upper leaves of healthy and diseased fig plants are presented in the Table 16a and Fig. 8a.

In the November, 2017 the Dinakar (25.81 mg/g) showed highest phenol content in its upper leaves, followed by Poona (17.97 mg/g) and Bellary (15.59 mg/g). These were statistically significant. The least phenol content was observed in Conadriya (9.48 mg/g), which was on par with Excel (9.83 mg/g). In the diseased plants, Poona recorded maximum phenol content (28.54 mg/g) which was on par with Dinakar (28.23 mg/g). The least phenol content was observed in Excel (16.76 mg/g) which was on par with Conadriya (16.86 mg/g).

However, in December, 2017 the highest phenol content in the upper leaves of healthy plant was observed in Dinakar (26.62 mg/g) which was significantly superior, followed by Poona (26.33 mg/g) and Dienna (18.88 mg/g). The phenol content of Dienna was on par with Bellary (17.77 mg/g). The least phenol content was observed in Conadriya (9.93 mg/g) and Excel (9.93 mg/g). Among the diseased plants, Poona (39.44 mg/g) showed highest phenol content, followed by Dinakar (33.82 mg/g) and Dienna (26.43 mg/g) and were significantly different from each other. The least phenol content was observed in Excel (16.69 mg/g) which was on par with Conadriya (17.44 mg/g).

Whereas, in the month of January, 2018 the highest phenol content was observed in Bellary (24.05 mg/g) which was significantly superior to other varieties, followed by Poona (20.39 mg/g) and Dinakar (19.48 mg/g). The least phenol content was recorded in Excel (9.28 mg/g) which was on par with Conadriya (9.28 mg/g). In the diseased plants among all other varieties Poona recorded (38.57 mg/g) maximum phenol content which was significantly superior over other varieties, followed by Bellary (29.77 mg/g). The Phenol content of Dienna was on par with Dinakar (23.87 mg/g). The least phenol content was observed in Conadriya (16.66 mg/g), followed by Excel (19.59 mg/g).

**Lower leaves**

The total phenols observed in the lower leaves of healthy and diseased fig plants are presented in the Table 16b and Fig. 8b.

In the November, 2017 the Dinakar (41.70 mg/g) showed highest phenol content in its lower leaves, followed by Poona (25.68 mg/g) and Bellary (22.45 mg/g). The least phenol content was observed in Conadriya (10.72 mg/g), followed by Excel

**Table 16a. Phenol content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

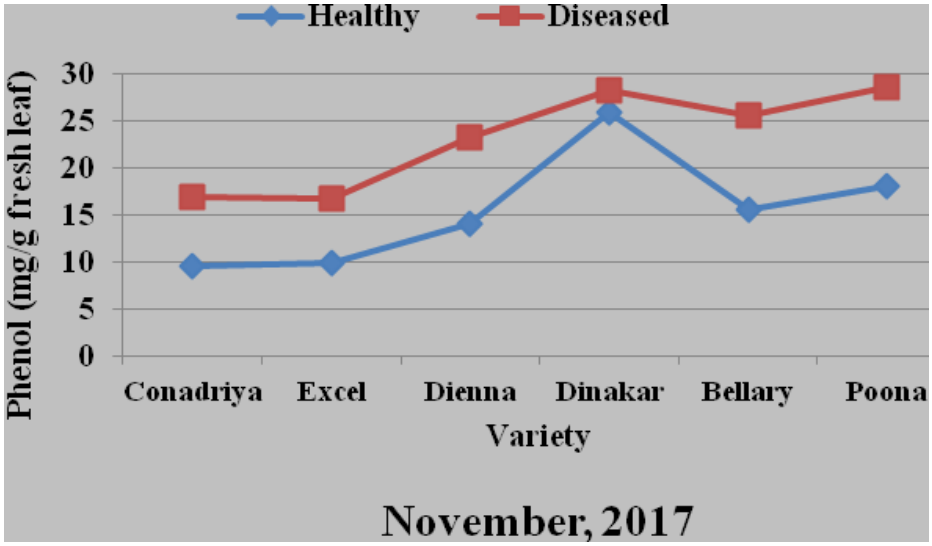
| Sl. No. | Variety | Phenol content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 9.48 | 16.86 | 9.93 | 17.44 | 9.48 | 16.66 | HS |
| 2 | Excel | 9.83 | 16.76 | 9.93 | 16.69 | 9.28 | 19.59 | HS |
| 3 | Dienna | 14.08 | 23.23 | 18.85 | 26.43 | 15.36 | 24.10 | HS |
| 4 | Dinakar | 25.81 | 28.23 | 26.62 | 33.82 | 19.48 | 23.87 | HS |
| 5 | Bellary | 15.59 | 25.49 | 17.77 | 24.17 | 24.05 | 29.77 | HS |
| 6 | Poona | 17.97 | 28.54 | 26.33 | 39.44 | 20.39 | 38.57 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.33 | 1.04 | 0.48 | 1.52 | 0.69 | 2.15 | |
| | Sample | 0.19 | 0.59 | 0.28 | 0.87 | 0.40 | 1.24 | |
| | V× S | 0.47 | 1.45 | 0.69 | 2.15 | 0.98 | 3.04 | |

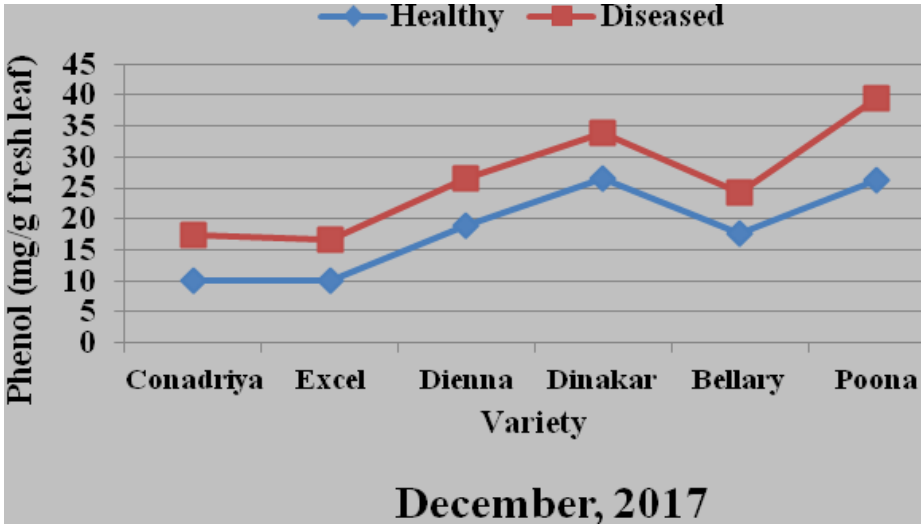
*Significance at 0.01
HS – Highly susceptible; S - Susceptible

**Table 16b. Phenol content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Phenol content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 10.72 | 25.13 | 12.09 | 26.47 | 14.02 | 23.76 | HS |
| 2 | Excel | 11.40 | 26.50 | 12.92 | 23.99 | 13.43 | 33.00 | HS |
| 3 | Dienna | 15.45 | 33.07 | 31.11 | 34.12 | 22.58 | 27.01 | HS |
| 4 | Dinakar | 41.70 | 49.41 | 38.43 | 41.31 | 34.65 | 46.72 | HS |
| 5 | Bellary | 22.45 | 54.80 | 26.20 | 31.70 | 33.46 | 46.82 | HS |
| 6 | Poona | 25.68 | 34.05 | 34.28 | 43.43 | 35.49 | 46.42 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.23 | 0.71 | 0.28 | 0.86 | 0.70 | 2.19 | |
| | Sample | 0.13 | 0.41 | 0.16 | 0.50 | 0.41 | 1.26 | |
| | V× S | 0.32 | 1.00 | 0.39 | 1.22 | 0.99 | 3.09 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible



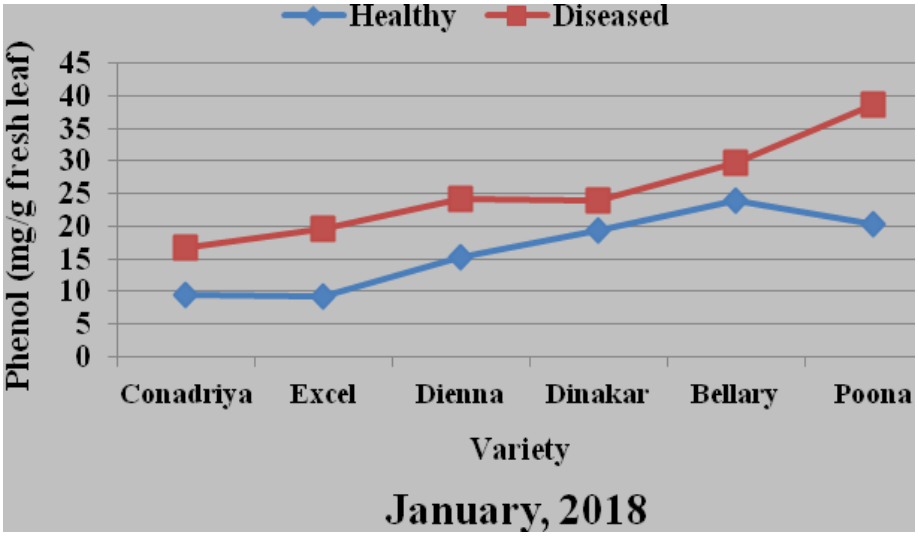




**Fig. 8a. Phenol content in the upper leaves of healthy and diseased fig varieties**

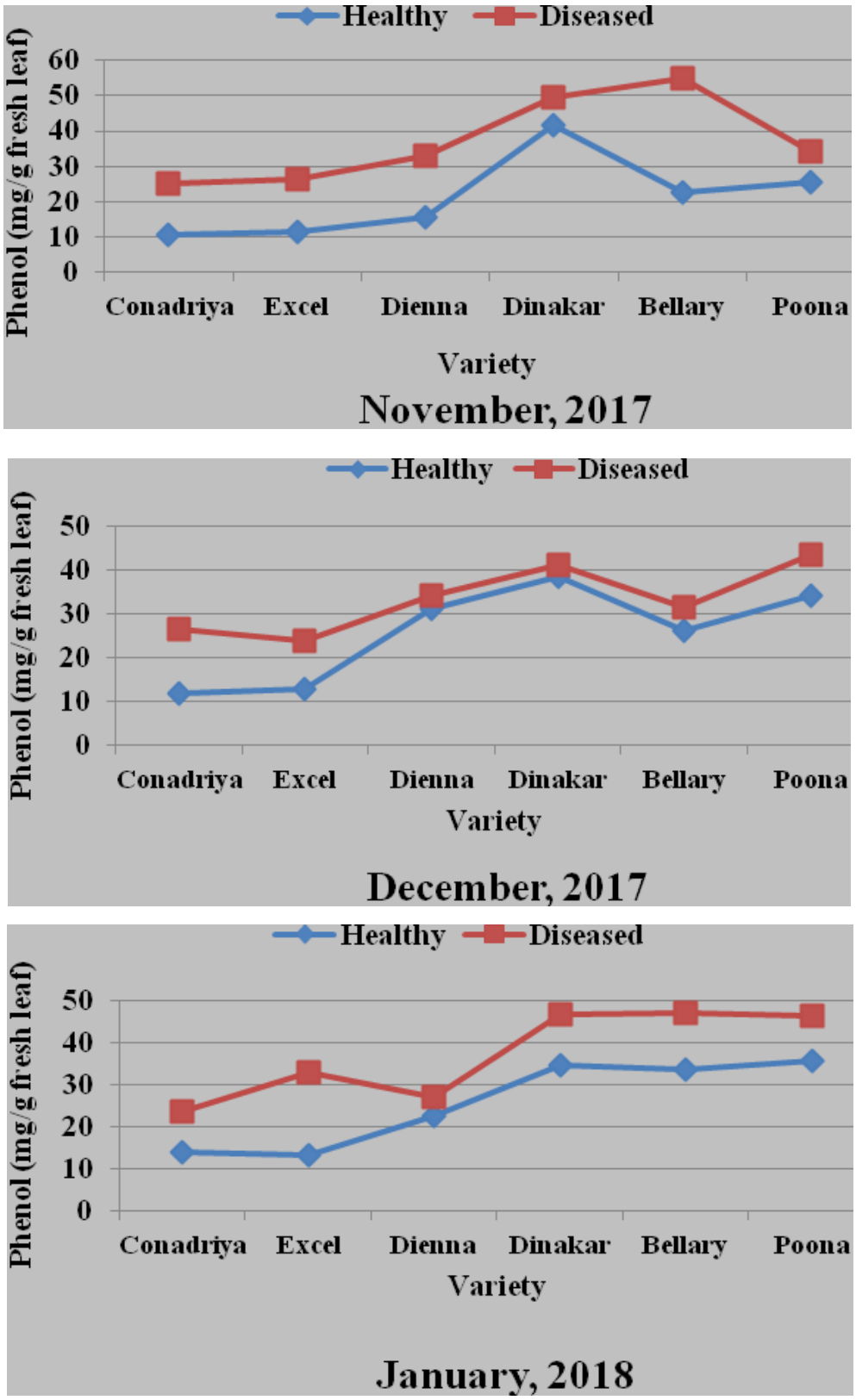



**Fig. 8b. Phenol content in the upper leaves of healthy and diseased fig varieties**

(11.40 mg/g) and Dienna (15.45 mg/g). These were statistically significant. In the diseased plants, Bellary recorded maximum phenol content (54.80 mg/g), followed by Dinakar (49.41 mg/g) and Poona (34.05 mg/g). The least phenol content was observed in Conadriya (25.13 mg/g), followed by Excel (26.50 mg/g) and Dienna (33.07 mg/g).

However, in December, 2017 the highest phenol content in the lower leaves of healthy plant was observed in Dinakar (38.43 mg/g) which was significantly superior, followed by Poona (34.28 mg/g) and Dienna (31.11 mg/g). The least phenol content was observed in Conadriya (12.09 mg/g) which was on par with Excel (12.92 mg/g). The pathogenesis affected the phenol content in the fig leaves. In the diseased condition, Poona (43.43 mg/g) recorded maximum phenol content and was statistically significant, followed by Dinakar (41.31 mg/g) and Dienna (34.12 mg/g). The least phenol content was observed in Excel (23.99 mg/g), followed by Conadriya (26.47 mg/g) and Bellary (31.70 mg/g).

Whereas, in the month of January, 2018 in the healthy condition, variety Poona (35.49 mg/g) recorded maximum phenols which was on par with Dinakar (34.65 mg/g) and Bellary (33.46 mg/g). The least phenol content was recorded in Excel (13.43 mg/g) which was on par with Conadriya (14.02 mg/g). In diseased condition, maximum total phenol content was recorded in Bellary (46.82 mg/g) which was on par with Dinakar (46.72 mg/g) and Poona (46.42 mg/g). The least phenol content was recorded in Conadriya (23.76 mg/g) followed by Dienna (27.01 mg/g) and Excel (33.00 mg/g).

#### 4.5.4.6 Chlorophyll a

The chlorophyll a (mg/g) content differed between the upper and lower leaves of the fig varieties.

**Upper leaves**

The Chlorophyll a content of upper leaves of diseased and healthy plants are presented in the Table 17a and Fig 9a.

In the month of November, 2017 in healthy plants the upper leaf of Conadriya (2.03 mg/g) recorded highest chlorophyll a content, followed by Dinakar (1.69 mg/g)

**Table 17a. Chlorophyll a content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

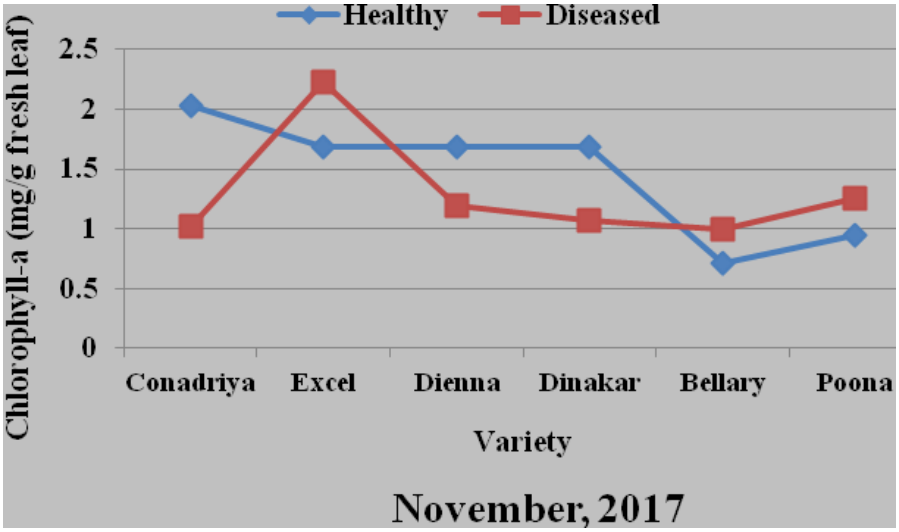
| Sl. No. | Variety | Chlorophyll a content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 2.03 | 1.02 | 0.41 | 0.59 | 0.40 | 0.60 | HS |
| 2 | Excel | 1.68 | 2.22 | 1.02 | 0.69 | 1.93 | 0.74 | HS |
| 3 | Dienna | 1.68 | 1.19 | 0.92 | 0.82 | 0.64 | 0.83 | HS |
| 4 | Dinakar | 1.69 | 1.07 | 1.14 | 1.14 | 0.78 | 1.23 | HS |
| 5 | Bellary | 0.71 | 1.00 | 0.54 | 0.79 | 0.30 | 0.79 | HS |
| 6 | Poona | 0.95 | 1.26 | 0.67 | 1.47 | 0.69 | 0.83 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.01 | 0.04 | 0.01 | 0.04 | 0.01 | 0.04 | |
| | Sample | 0.01 | 0.03 | 0.01 | 0.03 | 0.01 | 0.03 | |
| | V× S | 0.02 | 0.06 | 0.02 | 0.06 | 0.02 | 0.06 | |

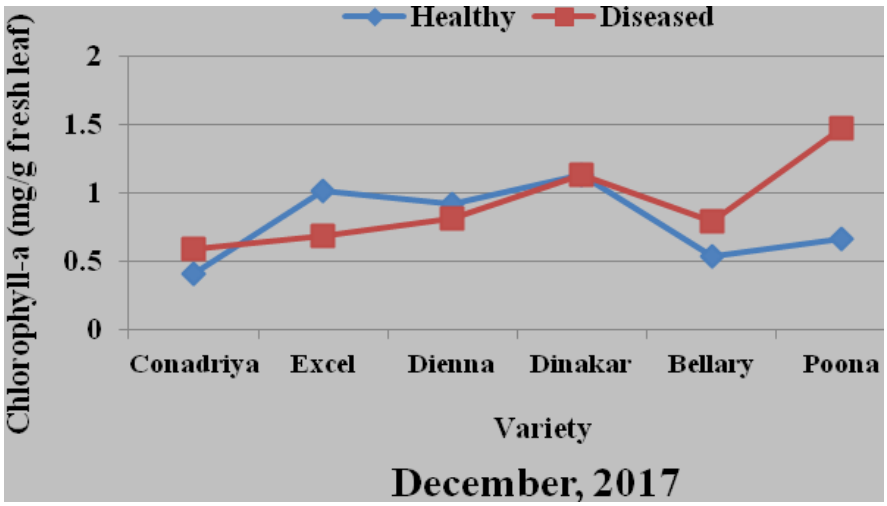
*Significance at 0.01
HS – Highly susceptible; S – Susceptible

**Table 17b. Chlorophyll a content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Chlorophyll a content (mg/g) of lower leaves | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 2.75 | 2.24 | 1.20 | 0.49 | 0.80 | 0.52 | HS |
| 2 | Excel | 1.72 | 1.41 | 1.65 | 1.15 | 1.85 | 1.21 | HS |
| 3 | Dienna | 1.36 | 1.26 | 1.27 | 0.92 | 1.18 | 0.93 | HS |
| 4 | Dinakar | 2.22 | 1.92 | 1.60 | 0.68 | 1.13 | 0.76 | HS |
| 5 | Bellary | 1.60 | 1.34 | 1.14 | 0.10 | 1.16 | 0.10 | HS |
| 6 | Poona | 1.31 | 0.71 | 0.89 | 0.28 | 1.50 | 0.33 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.04 | 0.11 | 0.05 | 0.14 | 0.03 | 0.09 | |
| | Sample | 0.02 | 0.06 | 0.03 | 0.08 | 0.02 | 0.05 | |
| | V× S | 0.05 | 0.16 | 0.07 | 0.20 | 0.04 | 0.12 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible



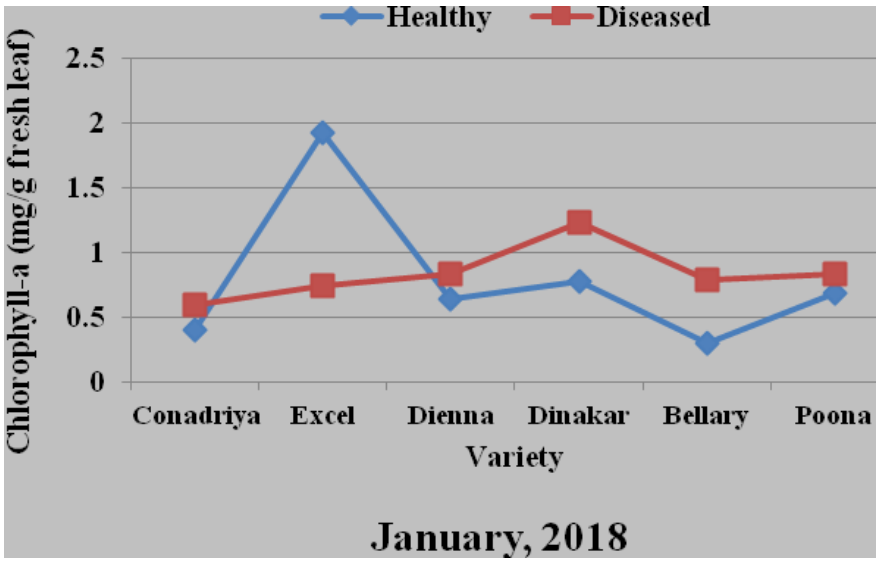
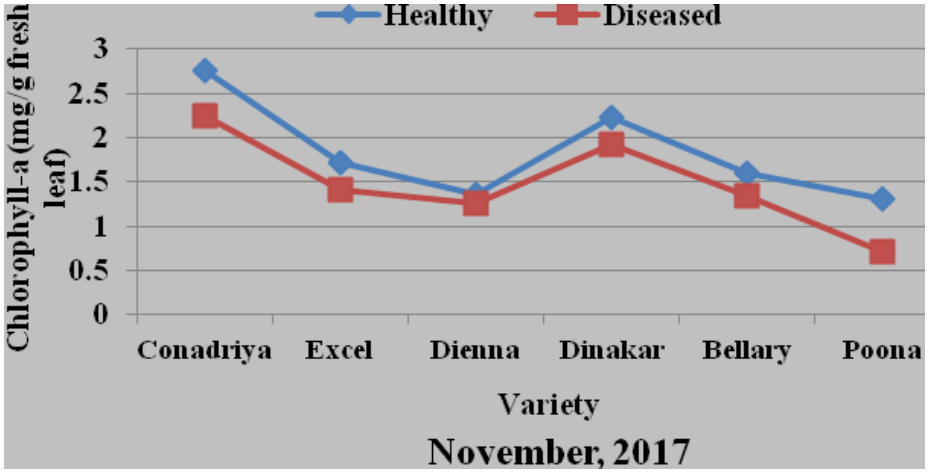
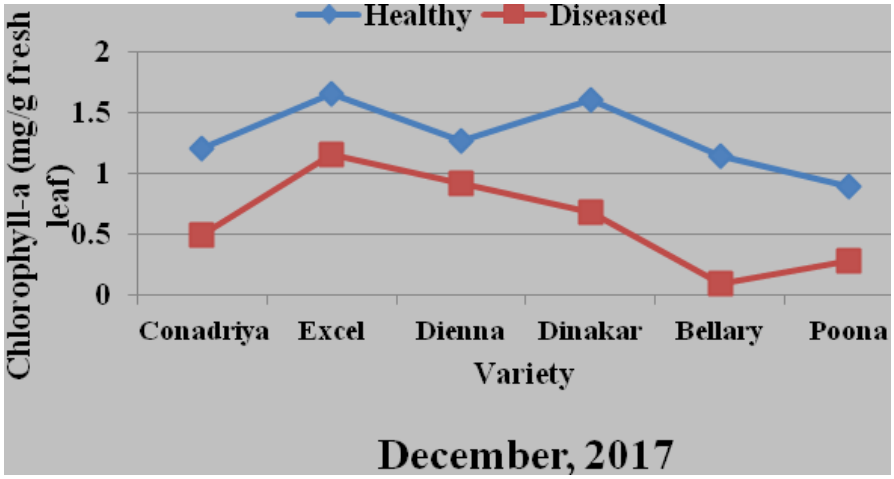




**Fig. 9a. Chlorophyll-a content in the upper leaves of healthy and diseased fig varieties**



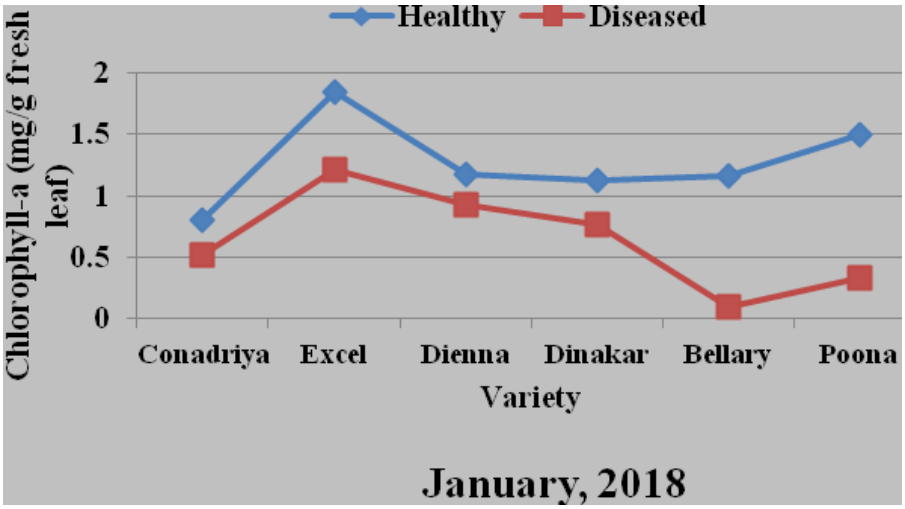




**Fig. 9b. Chlorophyll-a content in the lower leaves of healthy and diseased fig varieties**

which was found on par with Dienna (1.68 mg/g) and Excel (1.68 mg/g). The least chlorophyll-a content was observed in Bellary (0.71 mg/g), followed by Poona (0.95 mg/g). In the diseased plant the highest chlorophyll-a content was observed in Excel (2.22 mg/g), followed by Poona (1.26 mg/g) and Dienna (1.19 mg/g) and were found statistically significant. The lowest chlorophyll-a content was recorded in Bellary (1.00 mg/g) which was on par with Conadriya (1.02 mg/g).

The chlorophyll-a content in the December, 2017 was recorded in the upper leaves of both healthy and rust affected fig varieties. In the healthy plants the highest chlorophyll-a was observed in Dinakar (1.14 mg/g), which was significantly superior over other varieties, followed by Excel (1.02 mg/g) and Dienna (0.92 mg/g). The lowest chlorophyll-a was recorded in Conadriya (0.41 mg/g), followed by Bellary (0.54 mg/g) and Poona (0.67 mg/g) and were statistically significant. In the rust affected plants, the upper leaf of Poona (1.47 mg/g) recorded highest Chlorophyll-a content, followed by Dinakar (1.14 mg/g) and Dienna (0.82 mg/g) and were found to be statistically significant. The lowest chlorophyll-a content was observed in Conadriya (0.59 mg/g), followed by Excel (0.69 mg/g) and Bellary (0.79 mg/g) and varied significantly from each other.

In the month of January, 2018 in the healthy plants the highest chlorophyll-a content was recorded in Excel (1.93 mg/g), followed by Dinakar (0.78 mg/g) and Poona (0.69 mg/g). The lowest chlorophyll-a content was observed in Bellary (0.30 mg/g), followed by Conadriya (0.40 mg/g) and Dienna (0.64 mg/g). The chlorophyll-a content varied significantly between the varieties. In the rust affected plants the highest chlorophyll-a content was recorded in Dinakar (1.23 mg/g), which was significantly superior. The chlorophyll-a content of Poona (0.83 mg/g) was on par with Dienna (0.83 mg/g). The lowest chlorophyll-a content was observed in Conadriya (0.60 mg/g), followed by Excel (0.74 mg/g) which was on par with Bellary (0.79 mg/g).

**Lower leaves**

The Chlorophyll a content in the lower leaves of diseased and healthy plants are presented in the Table 17b and Fig. 9b.

In the month of November, 2017 among the healthy plants, the lower leaf of Conadriya (2.75 mg/g) recorded highest chlorophyll a content, followed by Dinakar (2.22 mg/g) and Excel (1.72 mg/g). The least chlorophyll-a content was observed in Poona (1.31 mg/g), followed by Dienna (1.36 mg/g) and Bellary (1.60 mg/g). All were found to be statistically significant. In the diseased plant the highest chlorophyll-a content was observed in Conadriya (2.24 mg/g), followed by Dinakar (1.92 mg/g). The chlorophyll-a content of Excel (1.41 mg/g) was found on par with Bellary (1.34 mg/g). The lowest chlorophyll-a content was recorded in Poona (0.71 mg/g), followed by Dienna (1.26 mg/g).

The chlorophyll-a content in the December, 2017 was recorded in the lower leaves of both healthy and rust infected fig varieties. In the healthy plants, the highest chlorophyll-a was observed in Excel (1.65 mg/g) which was on par with Dinakar (1.60 mg/g). The lowest chlorophyll-a was recorded in Poona (0.89 mg/g), followed by Bellary (1.14 mg/g) which was found on par with Conadriya (1.20 mg/g). In the diseased plants, the lower leaf of Excel (1.15 mg/g) recorded highest Chlorophyll-a content, followed by Dienna (0.92 mg/g) and Dinakar (0.68 mg/g) and were found to be statistically significant. The lowest chlorophyll-a content was observed in Bellary (0.10 mg/g), followed by Poona (0.28 mg/g) and Conadriya (0.49 mg/g) and varied significantly from each other. The chlorophyll-a content was drastically reduced in the rust affected plants compared to healthy plants.

In the month of January, 2018, in the healthy plants the highest chlorophyll-a content was recorded in Excel (1.85 mg/g), followed by Poona (1.50 mg/g) and Dienna (1.18 mg/g). The lowest chlorophyll-a content was observed in Conadriya (0.80 mg/g), followed by Dinakar (1.13 mg/g) and Bellary (1.16 mg/g). The chlorophyll-a content varied significantly between the varieties. In the rust infected plants, the highest chlorophyll-a content was recorded in Excel (1.21 mg/g), followed by Dienna (0.93 mg/g) and Dinakar (0.76 mg/g). The lowest chlorophyll-a content was observed in Bellary (0.10 mg/g), followed by Poona (0.33 mg/g) and Conadriya (0.52 mg/g). The chlorophyll-a content varied significantly between the varieties, it was observed that the chlorophyll-a content was less in diseased plant when compared to the healthy plants.

### 4.5.5.7 Chlorophyll b

The chlorophyll b (mg/g) content differed between the upper and lower leaves of the fig varieties.

**Upper leaves**

The Chlorophyll b content of upper leaves of diseased and healthy plants are presented in the Table 18a Fig. 10a.

In the month of November, 2017 the healthy leaves of Excel (0.80 mg/g) recorded highest chlorophyll b content, followed by Dinakar (0.60 mg/g) and Poona (0.48 mg/g) and varied significantly. The least chlorophyll-b content was observed in Bellary (0.15 mg/g), followed by Conadriya (0.22 mg/g) and Dienna (0.35 mg/g). In the diseased plants, the highest chlorophyll-b content was observed in Excel (0.99 mg/g), followed by Bellary (0.81 mg/g) and Dinakar (0.74 mg/g) and were statistically significant. The lowest chlorophyll-b content was recorded in Dienna (0.17 mg/g), followed by Poona (0.40 mg/g) and Conadriya (0.47 mg/g). The chlorophyll-b content varied significantly between the varieties.

During December, 2017, among healthy plants, chlorophyll-b content was maximum in Dienna (0.26 mg/g) which significantly superior, followed by Excel (0.18mg/g) which was found on par with Conadriya (0.17 mg/g) and Dinakar (0.16 mg/g). The lowest chlorophyll b content was recorded in Bellary (0.10 mg/g) and Poona (0.10 mg/g) and were on par with each other. In the diseased plant, the highest chlorophyll-b content was observed in Dinakar (0.53 mg/g), followed by Bellary (0.32 mg/g) and were statistically significant. The chlorophyll-b content of Poona (0.27 mg/g) was found on par with Excel (0.25 mg/g) and Dienna (0.24 mg/g). The lowest chlorophyll-b content was recorded in Conadriya (0.20 mg/g).

In the month of January, 2018, the healthy plants of Excel recorded the highest chlorophyll-b content which was found on par with Dinakar (0.15 mg/g). The lowest chlorophyll-b content was observed in Bellary (0.02 mg/g) and Conadriya (0.02 mg/g) and were on par with each other. In the rust affected plants, the highest chlorophyll-b content in the upper leaves was recorded by Poona (0.34 mg/g), which is on par with Bellary (0.33 mg/g). There was no significant differences between the chlorophyll-b

**Table 18a. Chlorophyll b content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

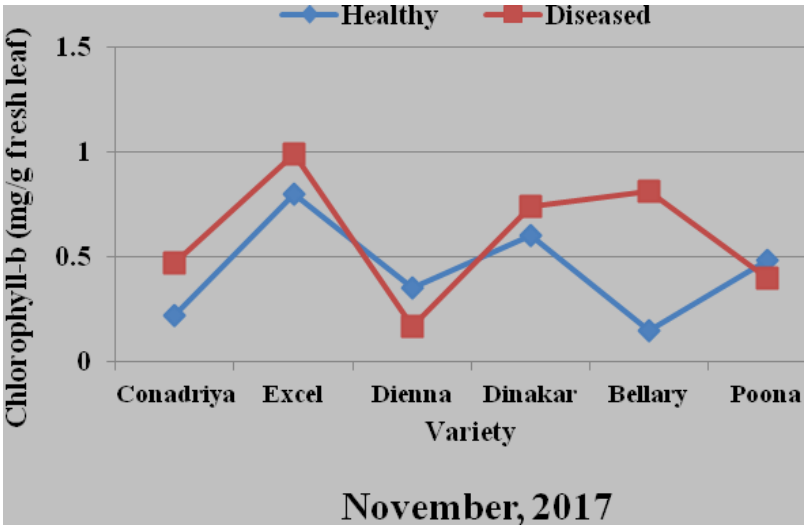
| Sl. No. | Variety | Chlorophyll b content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 0.22 | 0.47 | 0.17 | 0.20 | 0.02 | 0.21 | HS |
| 2 | Excel | 0.80 | 0.99 | 0.18 | 0.25 | 0.17 | 0.24 | HS |
| 3 | Dienna | 0.35 | 0.17 | 0.26 | 0.24 | 0.12 | 0.29 | HS |
| 4 | Dinakar | 0.60 | 0.74 | 0.16 | 0.53 | 0.15 | 0.30 | HS |
| 5 | Bellary | 0.15 | 0.81 | 0.10 | 0.32 | 0.02 | 0.33 | HS |
| 6 | Poona | 0.48 | 0.40 | 0.10 | 0.27 | 0.08 | 0.34 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.02 | 0.06 | 0.01 | 0.03 | 0.01 | 0.04 | |
| | Sample | 0.01 | 0.03 | 0.01 | 0.02 | 0.01 | 0.02 | |
| | V× S | 0.03 | 0.08 | 0.02 | 0.05 | 0.02 | 0.06 | |

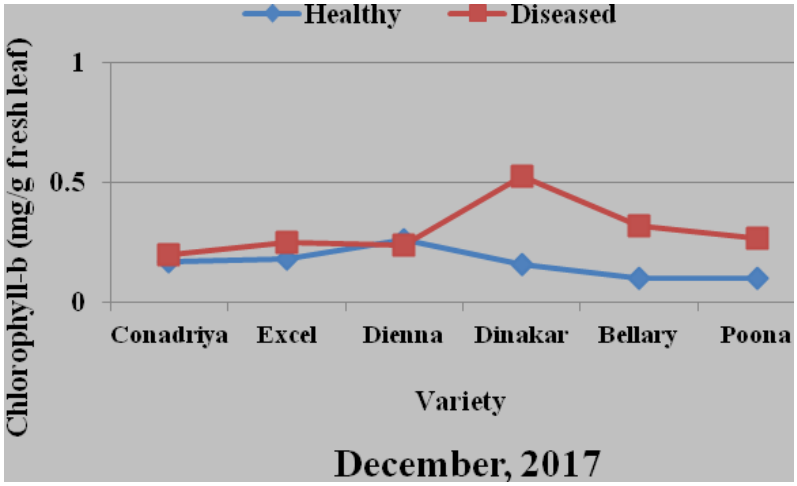
*Significance at 0.01
HS – Highly susceptible; S – Susceptible

**Table 18b. Chlorophyll b content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Chlorophyll b content (mg/g) of lower leaves | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 0.66 | 0.58 | 0.38 | 0.03 | 0.20 | 0.18 | HS |
| 2 | Excel | 0.91 | 0.60 | 0.79 | 0.22 | 0.29 | 0.27 | HS |
| 3 | Dienna | 0.92 | 0.40 | 0.90 | 0.39 | 0.14 | 0.41 | HS |
| 4 | Dinakar | 0.68 | 0.59 | 0.36 | 0.29 | 0.18 | 0.37 | HS |
| 5 | Bellary | 0.83 | 0.40 | 0.11 | 0.09 | 0.12 | 0.09 | HS |
| 6 | Poona | 0.61 | 0.50 | 0.50 | 0.14 | 0.10 | 0.15 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.01 | 0.04 | 0.01 | 0.03 | 0.019 | 0.006 | |
| | Sample | 0.01 | 0.03 | 0.01 | 0.02 | 0.011 | 0.003 | |
| | V× S | 0.02 | 0.06 | 0.01 | 0.04 | 0.027 | 0.009 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible



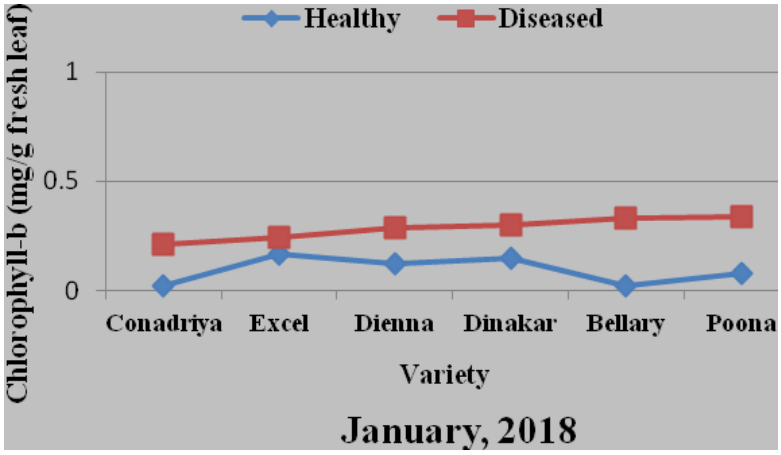
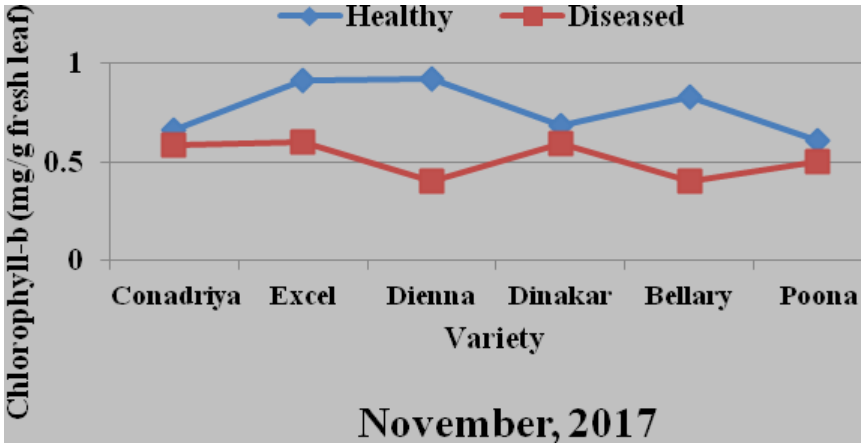
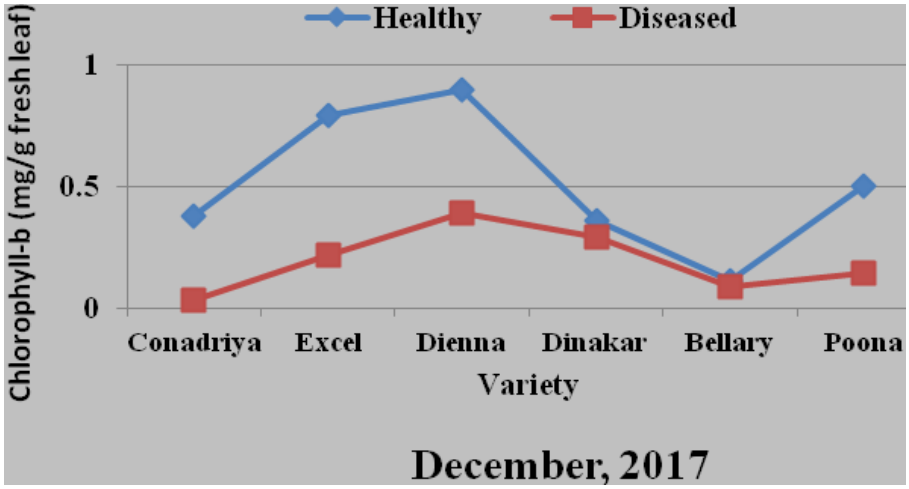




**Fig. 10a. Chlorophyll-b content in the upper leaves of healthy and diseased fig varieties**



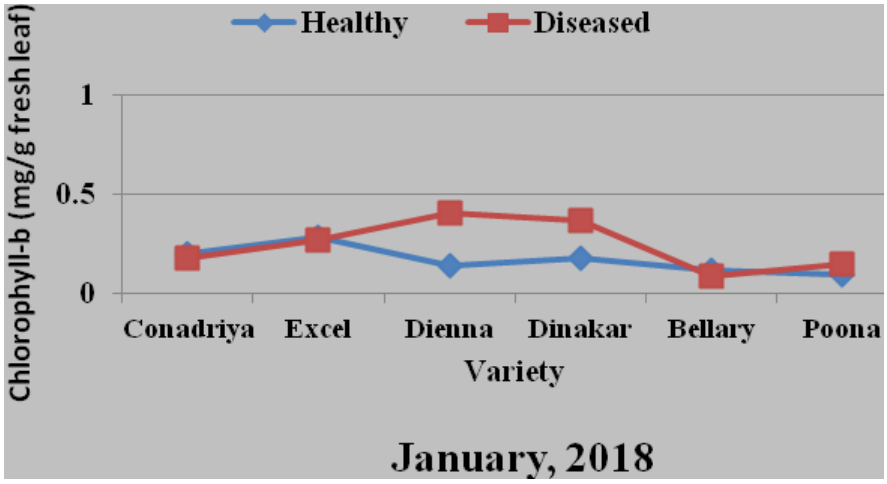




**Fig. 10b. Chlorophyll-b content in the lower leaves of healthy and diseased fig varieties**

content of Bellary (0.33 mg/g), Dinakar (0.30 mg/g) and Dienna (0.29 mg/g). The lowest chlorophyll-b content was observed in Conadriya (0.21 mg/g) which was found on par with Excel (0.24 mg/g).

**Lower leaves**

The Chlorophyll b content of lower leaves of diseased and healthy plants are presented in the Table 18b and Fig. 10b.

In the month of November, 2017, the lower leaf of healthy Dienna plants (0.92 mg/g) recorded highest chlorophyll b content, which was on par with Excel (0.91 mg/g). The least chlorophyll-b content was observed in Poona (0.61 mg/g), followed by Conadriya (0.66 mg/g) which is on par with Dinakar (0.68 mg/g). In the diseased plant, the highest chlorophyll-b content was observed in Excel (0.60 mg/g) which was found on par with Dinakar (0.59 mg/g) and Conadriya (0.58 mg/g). The lowest chlorophyll-b content was recorded in Dienna (0.40 mg/g) and Bellary (0.40mg/g).

During December, 2017 chlorophyll-b content was recorded in the lower leaves of both healthy and rust affected fig varieties. In the healthy plants, the highest chlorophyll-b content was recorded in Dienna (0.90 mg/g), followed by Excel (0.79 mg/g) and Poona (0.50 mg/g) and are statistically significant. The lowest Chlorophyll-b content was recorded in Bellary (0.11 mg/g), followed by Dinakar (0.36 mg/g) which was found on par with Conadriya (0.38 mg/g). In the diseased plant, the highest chlorophyll-b content was observed in Dienna (0.39 mg/g), followed by Dinakar (0.29 mg/g) and Excel (0.22 mg/g). The lowest chlorophyll-b content was recorded in Conadriya (0.03 mg/g), followed by Bellary (0.09 mg/g). The chlorophyll-b content varied significantly.

In the month of January, 2018, in the healthy plants of Excel (0.29 mg/g) chlorophyll-b content was recorded, followed by Conadriya (0.20 mg/g) and Dienna (0.18 mg/g). The lowest chlorophyll-b content was observed in Poona (0.10 mg/g), followed by Bellary (0.12 mg/g) and Dinakar (0.18 mg/g) and were found statistically significant. In the rust affected plants, the highest chlorophyll-b content in the lower leaves was recorded in Dienna (0.41 mg/g), followed by Dinakar (0.37 mg/g) and Excel (0.27 mg/g). The lowest chlorophyll-b content was observed in Bellary (0.09

mg/g), followed by Poona (0.15 mg/g) and Conadriya (0.18 mg/g). The chlorophyll-b content varied significantly.

#### 4.5.5.8 Total chlorophyll

The total chlorophyll (mg/g) content differed between the upper and lower leaves of the fig varieties.

**Upper leaves**

The total chlorophyll content of upper leaves of diseased and healthy plants are presented in the Table 19a and 11a.

In the month of November, 2017, the upper leaves of healthy plants of Excel (2.48 mg/g) recorded highest total chlorophyll content, followed by Dinakar (2.34 mg/g) and Conadriya (2.25 mg/g). The least chlorophyll content was observed in Bellary (0.86 mg/g), followed by Poona (1.43 mg/g) and Dienna (1.78 mg/g). In the rust affected plants, the highest total chlorophyll content was observed in Excel (3.16 mg/g), followed by Bellary (1.96 mg/g) and Dinakar (1.86 mg/g). The lowest chlorophyll content was observed in Dienna (1.36 mg/g), followed by Conadriya (1.49 mg/g) and Poona (1.66 mg/g). The total chlorophyll content varied significantly between the varieties in both healthy and diseased condition.

During December, 2017 the highest chlorophyll content in the healthy leaf was recorded in Dinakar (1.30 mg/g), followed by Excel (1.20 mg/g) which was found on par with Dienna (1.18 mg/g). The least chlorophyll content was recorded in Conadriya (0.58 mg/g), followed by Bellary (0.64 mg/g) and Poona (0.78 mg/g) and were statistically significant. In the diseased condition highest chlorophyll content was observed in Dinakar (1.78 mg/g), which was found on par with Poona (1.75 mg/g). The lowest chlorophyll content was observed in Conadriya (0.81 mg/g), followed by Excel (0.96 mg/g) and Dienna (1.06 mg/g) and were found statistically significant.

In the month of January, 2018 in the upper leaves of healthy plants, the highest total chlorophyll content was recorded in Excel (2.01 mg/g), followed by Dinakar (0.90 mg/g) and Dienna (0.79 mg/g). The lowest chlorophyll content was observed in Bellary (0.33 mg/g), followed by Conadriya (0.42 mg/g) and Poona (0.70

**Table 19a. Total chlorophyll content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

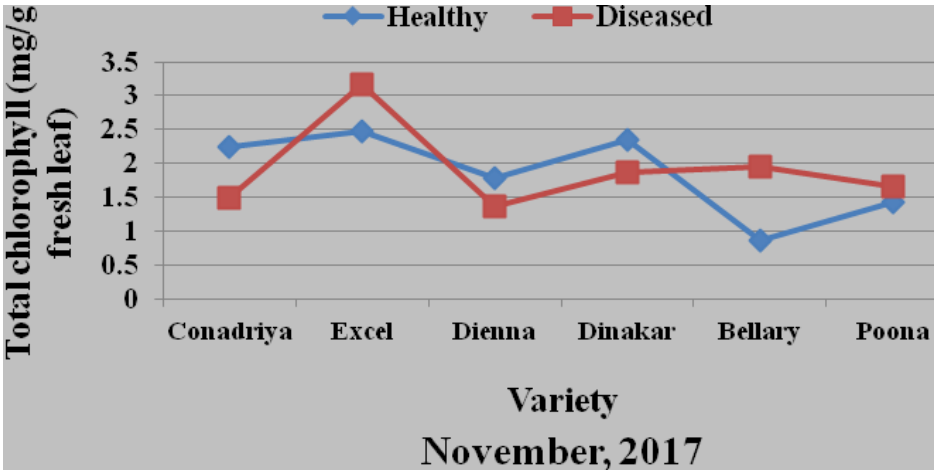
| Sl. No. | Variety | Total chlorophyll content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 2.25 | 1.49 | 0.58 | 0.81 | 0.42 | 0.82 | HS |
| 2 | Excel | 2.48 | 3.16 | 1.20 | 0.96 | 2.01 | 0.98 | HS |
| 3 | Dienna | 1.78 | 1.36 | 1.18 | 1.06 | 0.79 | 1.12 | HS |
| 4 | Dinakar | 2.34 | 1.86 | 1.30 | 1.78 | 0.90 | 1.55 | HS |
| 5 | Bellary | 0.86 | 1.96 | 0.64 | 1.15 | 0.33 | 1.13 | HS |
| 6 | Poona | 1.43 | 1.66 | 0.78 | 1.75 | 0.70 | 1.15 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.02 | 0.05 | 0.01 | 0.04 | 0.01 | 0.03 | |
| | Sample | 0.01 | 0.03 | 0.01 | 0.02 | 0.01 | 0.02 | |
| | V× S | 0.02 | 0.07 | 0.02 | 0.05 | 0.01 | 0.05 | |

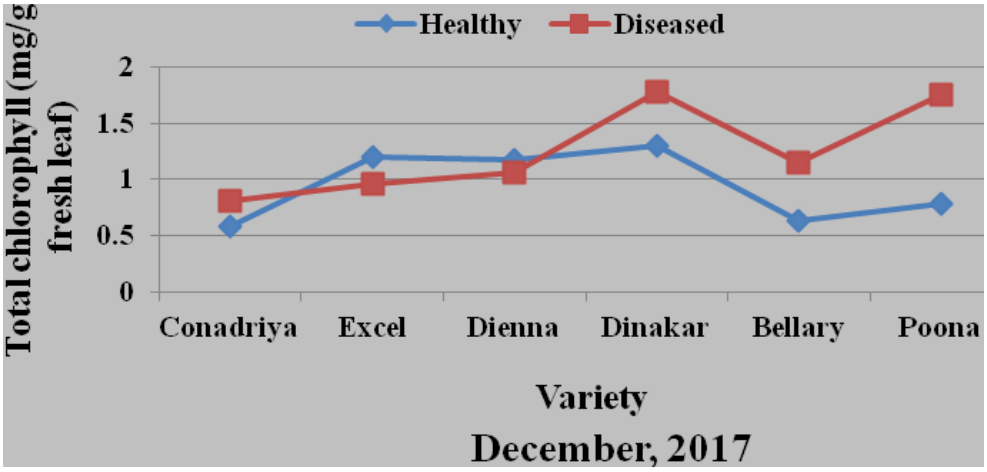
*Significance at 0.01
HS – Highly susceptible; S – Susceptible

**Table 19b. Total chlorophyll content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Total chlorophyll content (mg/g) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Health | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 3.41 | 2.82 | 1.79 | 0.53 | 1.00 | 0.69 | HS |
| 2 | Excel | 2.63 | 2.02 | 2.48 | 1.51 | 2.17 | 1.59 | HS |
| 3 | Dienna | 2.32 | 1.66 | 2.20 | 1.32 | 1.44 | 1.16 | HS |
| 4 | Dinakar | 2.83 | 2.40 | 1.96 | 0.98 | 1.34 | 1.13 | HS |
| 5 | Bellary | 2.43 | 1.73 | 1.26 | 0.91 | 1.28 | 0.99 | HS |
| 6 | Poona | 1.97 | 1.20 | 1.50 | 0.95 | 1.61 | 0.59 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.02 | 0.05 | 0.01 | 0.04 | 0.01 | 0.03 | |
| | Sample | 0.01 | 0.03 | 0.01 | 0.03 | 0.01 | 0.02 | |
| | V× S | 0.02 | 0.06 | 0.02 | 0.06 | 0.01 | 0.04 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible



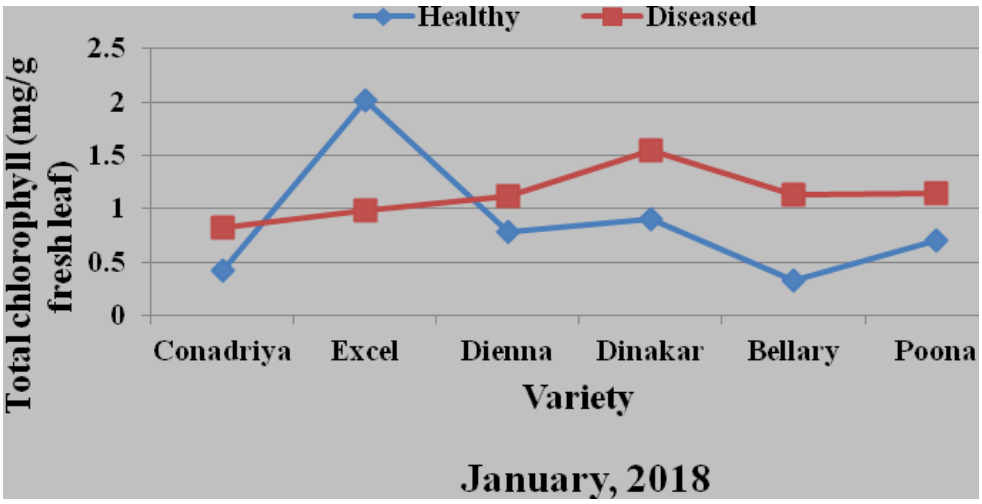
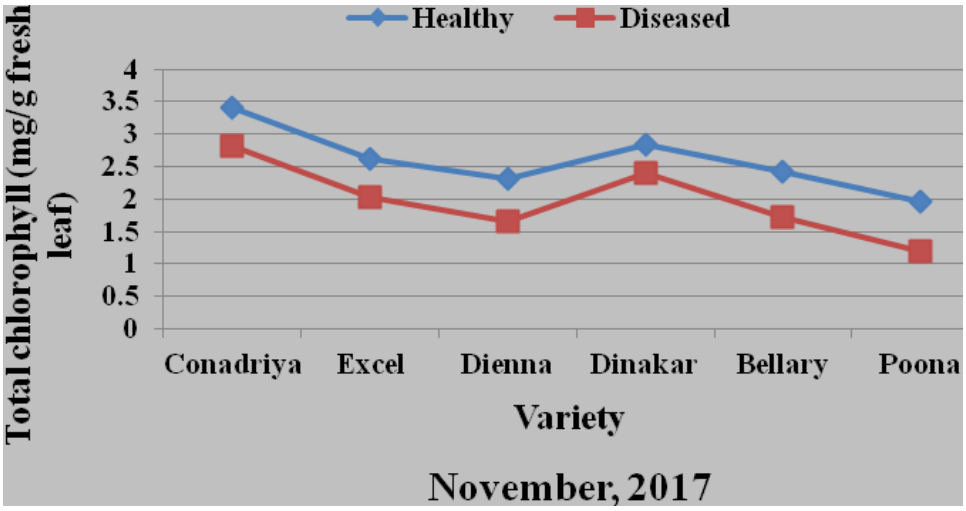
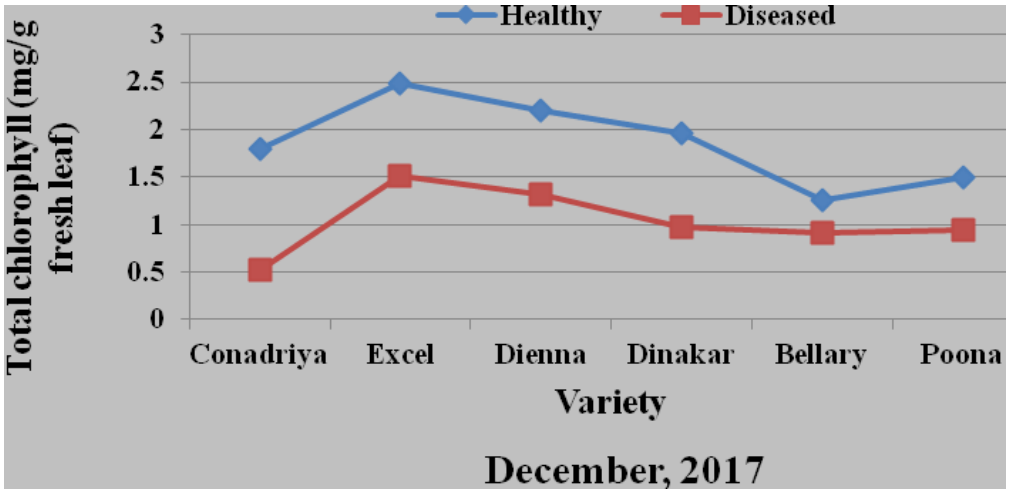




**Fig. 11a. Total chlorophyll content in the upper leaves of healthy and diseased fig varieties**



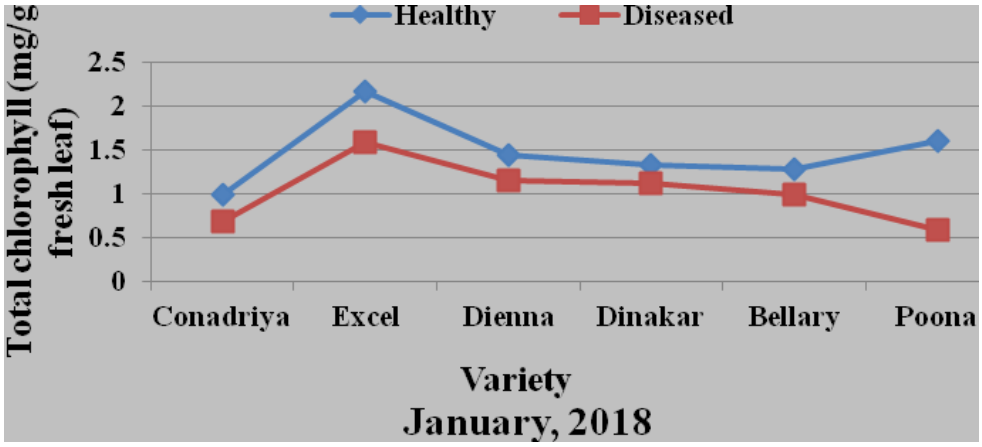




**Fig. 11b. Total chlorophyll content in the lower leaves of healthy and diseased fig varieties**

mg/g) and were found to be statistically significant. In the rust affected plant the highest total chlorophyll content was observed in Dinakar (1.55 mg/g), which was significantly superior, followed by Poona (1.15 mg/g), which was found on par with Bellary (1.13 mg/g) and Dienna (1.12 mg/g). The lowest chlorophyll content was observed in Conadriya (0.82 mg/g), followed by Excel (0.98 mg/g) and were significantly different.

**Lower leaves**

The total chlorophyll content in the lower leaves of diseased and healthy plants are presented in the Table 19b and Fig. 11b.

In the month of November, 2017 in the lower leaves of healthy plants, Conadriya (3.41 mg/g) recorded highest total chlorophyll content, followed by Dinakar (2.83 mg/g) and Excel (2.63 mg/g). The least chlorophyll content was observed in Poona (1.97 mg/g), followed by Dienna (2.32 mg/g) and Bellary (2.43 mg/g). In the rust affected plants, the highest chlorophyll content was observed in Conadriya (2.82 mg/g), followed by Dinakar (2.40 mg/g) and Excel (2.02 mg/g). The lowest chlorophyll content was observed in Poona (1.20 mg/g), followed by Dienna (1.66 mg/g) and Bellary (1.73 mg/g). The total chlorophyll content varied significantly between the varieties in both healthy and diseased condition

The total chlorophyll content during December, 2017, was highest in healthy plants of Excel (2.48 mg/g), followed by Dienna (2.20 mg/g) and Dinakar (1.96 mg/g). The least chlorophyll content was recorded in Bellary (1.26 mg/g), followed by Poona (1.50 mg/g) and Conadriya (1.79 mg/g) and were found statistically significant. In the diseased condition highest chlorophyll content was observed in Excel (1.51 mg/g), followed by Dienna (1.32 mg/g) and were significantly superior. The total chlorophyll content of Dinakar (0.98 mg/g) was on par with Poona (0.95 mg/g). The lowest chlorophyll content was observed in Conadriya (0.53 mg/g), followed by Bellary (0.91 mg/g) and was on par with Poona (0.95 mg/g).

In the month of January, 2018 in the lower leaves of healthy plants recorded the highest total chlorophyll content in Excel (2.17 mg/g), followed by Poona (1.61 mg/g) and Dienna (1.44 mg/g). The lowest chlorophyll content was observed in Conadriya (1.00 mg/g), followed by Bellary (1.28 mg/g) and Dinakar (1.34 mg/g) and

were found to be statistically significant. In the rust infected plant the maximum total chlorophyll content was observed in Excel (1.59 mg/g), which was significantly superior, followed by Dienna (1.16 mg/g), which was found on par with Dinakar (1.13 mg/g). The lowest chlorophyll content was observed in Poona (0.59 mg/g), followed by Conadriya (0.69 mg/g) which were on par with each other and were significantly different from other varieties.

**4.5.5.9 Epicuticular Wax**

**Upper leaves**

The epicuticular wax content in the upper leaves of healthy and diseased fig plants are presented in the Table 20a and Fig. 12a.

The analysis of epicuticular wax during the month of November, 2017 revealed that in the healthy condition, highest wax content was observed in Dinakar (0.56 mg/cm$^2$) and was found statistically significant, followed by Poona (0.46 mg/cm$^2$) and Dienna (0.34 mg/cm$^2$) which was on par with Conadriya (0.32 mg/cm$^2$) and Bellary (0.31 mg/cm$^2$). The least wax content was observed in Excel (0.15 mg/cm$^2$). In the diseased condition highest wax content was observed in Dinakar (0.39 mg/cm$^2$), followed by Conadriya (0.34 mg/cm$^2$) which was found on par with Poona (0.33 mg/cm$^2$) and Excel (0.29 mg/cm$^2$). The least wax content was observed in Bellary (0.26 mg/cm$^2$) which is on par with Dienna (0.27 mg/15cm$^2$) and Excel (0.29 mg/cm$^2$).

In the month of December, 2017 the upper leaves of healthy Dinakar (0.63 mg/cm$^2$) recorded maximum epicuticular wax content, which was found significantly superior over Poona (0.54 mg/cm$^2$) and Bellary (0.53 mg/cm$^2$). The least wax content was observed in Excel (0.22 mg/cm$^2$), followed by Dienna (0.32 mg/cm$^2$) and Conadriya (0.35 mg/cm$^2$). In the diseased condition, Dinakar (0.66 mg/cm$^2$) recorded maximum wax, followed by Poona (0.52 mg/cm$^2$) and Bellary (0.50 mg/cm$^2$). The least wax content was observed in Excel (0.26 mg/cm$^2$), followed by Conadriya (0.35 mg/cm$^2$) and Dienna (0.36 mg/cm$^2$). The wax content varied significantly among the varieties.

**Table 20a. Wax content in the upper leaves of healthy and rust infected fig varieties at monthly intervals**

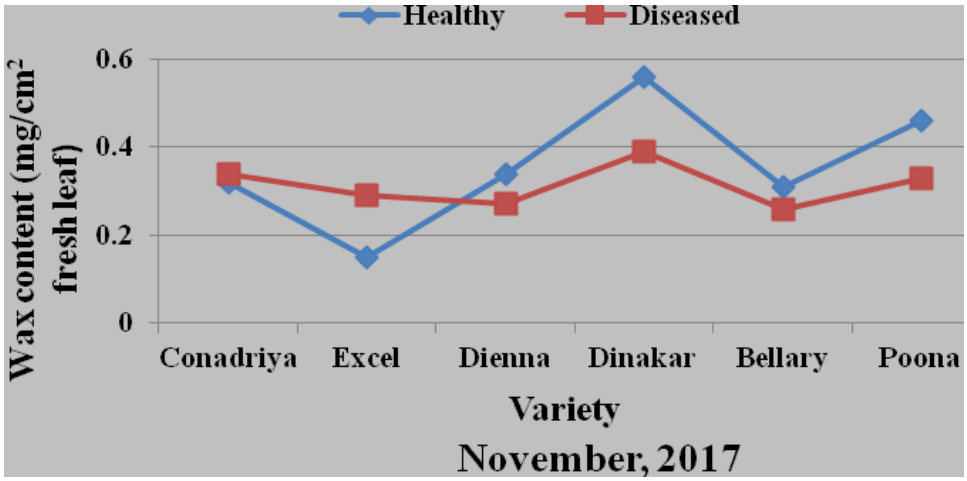
| Sl. No. | Variety | Wax content (mg per $cm^2$) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 0.32 | 0.34 | 0.35 | 0.35 | 0.44 | 0.35 | HS |
| 2 | Excel | 0.15 | 0.29 | 0.22 | 0.26 | 0.24 | 0.22 | HS |
| 3 | Dienna | 0.34 | 0.27 | 0.32 | 0.36 | 0.28 | 0.21 | HS |
| 4 | Dinakar | 0.56 | 0.39 | 0.63 | 0.66 | 0.56 | 0.72 | HS |
| 5 | Bellary | 0.31 | 0.26 | 0.53 | 0.50 | 0.58 | 0.59 | HS |
| 6 | Poona | 0.46 | 0.33 | 0.54 | 0.52 | 0.61 | 0.55 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.01 | 0.03 | 0.004 | 0.012 | 0.003 | 0.008 | |
| | Sample | 0.01 | 0.02 | 0.002 | 0.007 | 0.002 | 0.005 | |
| | V× S | 0.02 | 0.05 | 0.005 | 0.017 | 0.004 | 0.012 | |

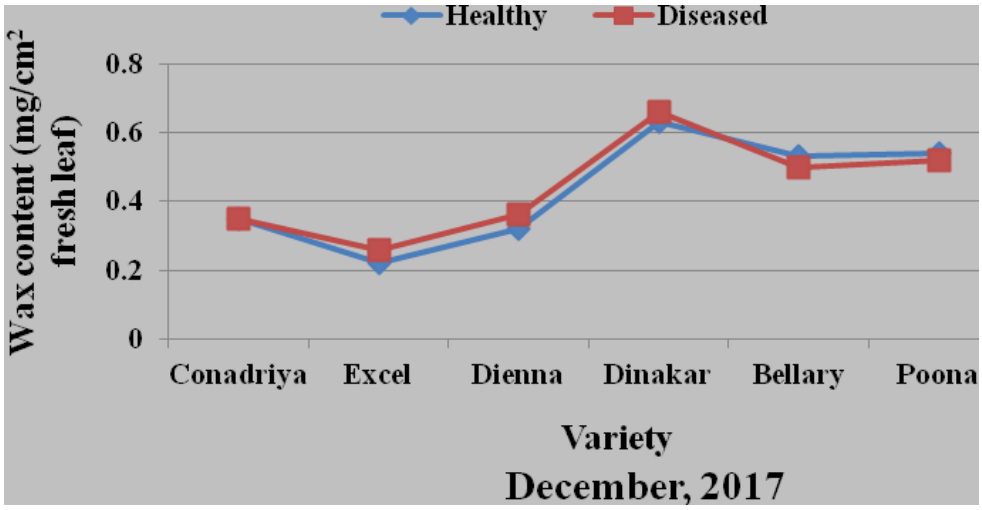
*Significance at 0.01
HS – Highly susceptible; S - Susceptible

**Table 20b. Wax content in the lower leaves of healthy and rust infected fig varieties at monthly intervals**

| Sl. No. | Variety | Wax content (mg per $cm^2$) | | | | | | Disease reaction |
|---|---|---|---|---|---|---|---|---|
| | | November 2017 | | December 2017 | | January 2018 | | |
| | | Healthy | Diseased | Healthy | Diseased | Healthy | Diseased | |
| 1 | Conadriya | 0.28 | 0.16 | 0.28 | 0.18 | 0.39 | 0.34 | HS |
| 2 | Excel | 0.12 | 0.18 | 0.13 | 0.21 | 0.19 | 0.14 | HS |
| 3 | Dienna | 0.19 | 0.19 | 0.21 | 0.23 | 0.29 | 0.15 | HS |
| 4 | Dinakar | 0.20 | 0.29 | 0.27 | 0.28 | 0.16 | 0.44 | HS |
| 5 | Bellary | 0.18 | 0.16 | 0.34 | 0.27 | 0.37 | 0.23 | HS |
| 6 | Poona | 0.18 | 0.13 | 0.41 | 0.36 | 0.33 | 0.26 | S |
| | | S.Em± | CD* | S.Em± | CD* | S.Em± | CD* | |
| | Variety | 0.002 | 0.007 | 0.006 | 0.018 | 0.005 | 0.015 | |
| | Sample | 0.001 | 0.004 | 0.003 | 0.011 | 0.003 | 0.009 | |
| | V× S | 0.003 | 0.01 | 0.008 | 0.026 | 0.007 | 0.021 | |

*Significance at 0.01
HS – Highly susceptible; S - Susceptible



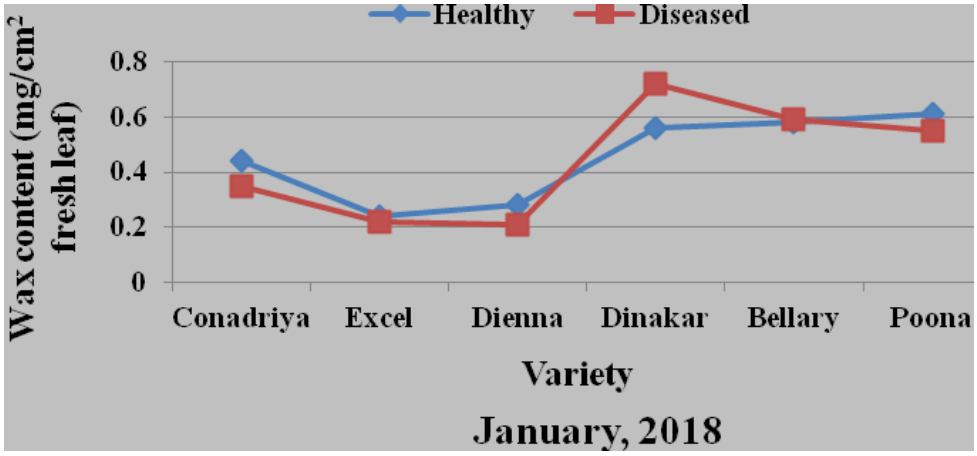
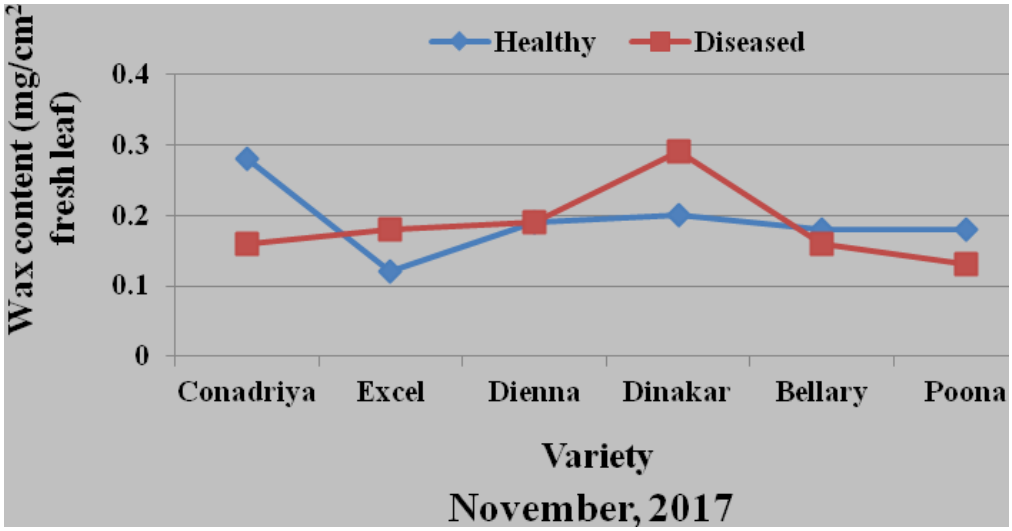
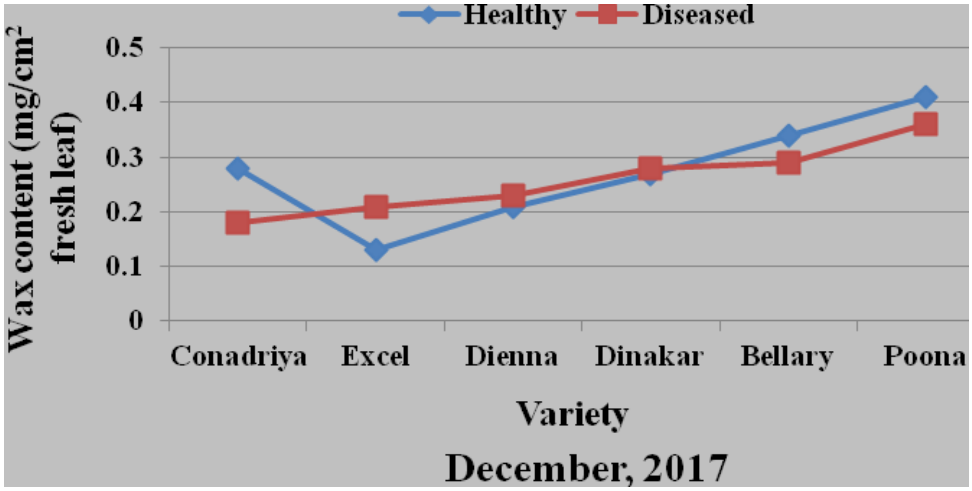




**Fig. 12a. Wax content in the upper leaves of healthy and diseased fig varieties**



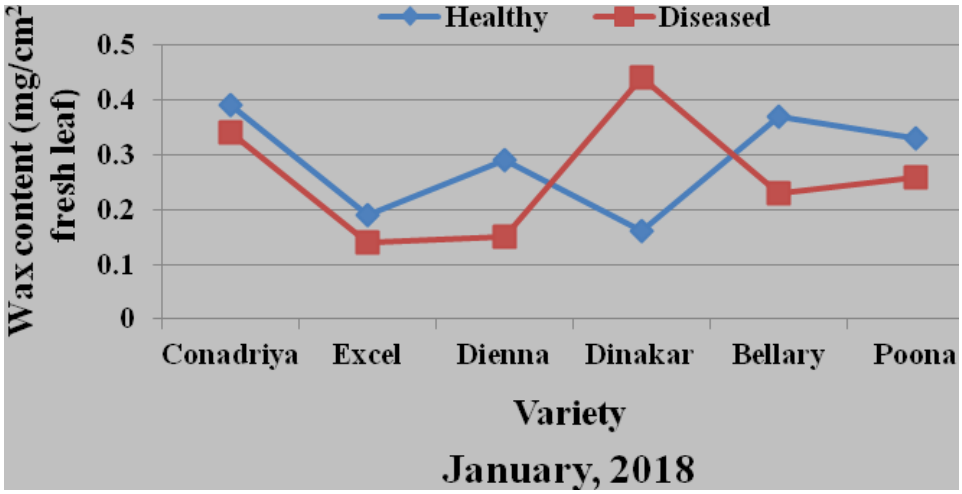




**Fig. 12b. Wax content in the lower leaves of healthy and diseased fig varieties**

Whereas in the month of January, 2018 in the healthy plants, Poona recorded maximum (0.61 mg/cm$^2$) wax content, followed by Bellary (0.58 mg/cm$^2$) and Dinakar (0.56 mg/cm$^2$). The least wax content was observed in Excel (0.24 mg/cm$^2$), followed by Dienna (0.28 mg/cm$^2$) and Conadriya (0.44 mg/cm$^2$) and were statistically significant. In the diseased plants, Dinakar (0.72 mg/cm$^2$) recorded maximum wax content, followed by Bellary (0.59 mg/cm$^2$) and Poona (0.55 mg/cm$^2$). The least wax content was observed in Dienna (0.21 mg/cm$^2$), followed by Excel (0.22 mg/cm$^2$) and Conadriya (0.35 mg/cm$^2$). These are found to be statistically significant.

**Lower leaves**

The epicuticular wax observed in the lower leaves of healthy and diseased fig plants are presented in the Table 20b Fig. 12b.

The analysis of epicuticular wax in the month of November, 2017 revealed that in the healthy condition highest wax content was recorded in the lower leaf of Conadriya (0.28 mg/cm$^2$) and was found statistically significant over Dinakar (0.20 mg/15 cm$^2$) which was on par with Dienna (0.19 mg/cm$^2$). The wax content of Bellary (0.18 mg/cm$^2$) is on par with Poona (0.18 mg/cm$^2$) and the least wax content was observed in Excel (0.12 mg/cm$^2$). In the diseased condition, highest wax content was observed in Dinakar (0.29 mg/cm$^2$) which is significantly superior followed by Dienna (0.19 mg/cm$^2$) which was found on par with Excel (0.18 mg/cm$^2$). The least wax content was observed in Poona (0.13 mg/cm$^2$), followed by Conadriya (0.16 mg/cm$^2$) and on par with Bellary (0.16 mg/cm$^2$).

In the month of December, 2017 the lower leaf of healthy Poona (0.41 mg/cm$^2$) recorded maximum epicuticular wax content, followed by Bellary (0.34 mg/cm2) and Conadriya (0.28 mg/cm$^2$). The least wax content was observed in Excel (0.13 mg/cm$^2$), followed by Dienna (0.21 mg/cm$^2$) and Dinakar (0.27 mg/cm$^2$). In the diseased condition Poona (0.36 mg/cm$^2$) recorded maximum wax, followed by Dinakar (0.28 mg/cm$^2$) which was on par with Bellary (0.27 mg/cm$^2$). The least wax content was observed in Conadriya (0.18 mg/cm$^2$), followed by Excel (0.21 mg/cm$^2$) and Dienna (0.23 mg/cm$^2$) and varied significantly.

Whereas, in the month of January, 2018 in the healthy plants Conadriya (0.39 mg/cm$^2$) recorded maximum wax content, followed by Bellary (0.37 mg/cm$^2$) and Poona (0.33 mg/cm$^2$). The least wax content was observed in Dinakar (0.16 mg/cm$^2$), followed by Excel (0.19 mg/cm$^2$) and Dienna (0.29 mg/cm$^2$) and were found statistically significant. In the diseased plants, Dinakar (0.44 mg/cm$^2$) recorded maximum wax content, followed by Conadriya (0.34 mg/cm$^2$) and Poona (0.26 mg/cm$^2$). The least wax content was observed in Excel (0.14 mg/cm$^2$) which was on par with Dienna (0.15 mg/cm$^2$).

## 4.6 Management of fig rust using fungicides, biorationals and bioagents

### 4.6.1 *In vitro* evaluation of fungicides, biorationals and bioagents

The Efficacy of fungicides was tested *in vitro* as explained in material and methods. The per cent inhibition of the uredospore germination of *C. fici* at different concentrations over control was calculated.

Seven systemic fungicides *viz.*, azoxystrobin, carbendazim, difenoconazole, hexaconazole, kresoxim methyl, propiconazole and tebuconazole were evaluated against *C. fici* in the laboratory. The data on per cent reduction in spore germination as influenced by different fungicides at three concentration are presented in Table 21a and Fig. 13. Among systemic fungicides at 1000 ppm concentration difenconazole, carbendazim and kresoxim methyl gave 100 per cent spore inhibiton. Hexaconazole gave least inhibition (93.47%), followed by azoxystrobin (96.98%) and tebuconazole (98.97%). At 500 ppm, propiconazole gave maximum inhibition (98.56%) which was on par with carbendazim (98.37%) followed by difenconazole (96.02%). At the minimum concentration tested (250 ppm), propiconazole found to be highly effective in inhibiting spore germination which gave 97.68 per cent inhibition and was significantly superior to other fungicides tested followed by difenconazole (94.70%), which was on par with kreoxim methyl (94.73%). Least inhibition at minimum concentration (250 ppm) was observed in azoxystrobin (88.11%) on par with hexaconazole (88.74%), followed by tebuconazole (92.57%).

The five non systemic fungicides, copper oxychloride, chlorothalonil, copper hydroxide, mancozeb and zineb were evaluated at four concentration *viz.*, 500, 1000, 2500 and 3000 ppm. The results presented in the Table 21b and Fig. 14 revealed that

**Table 21a. *In vitro* per cent inhibition of uredospore germination by systemic fungicides**

| Sl. No. | Fungicide | Per cent inhibition of uredospore germination | | | |
|---|---|---|---|---|---|
| | | Concentration (ppm) | | | |
| | | 250 | 500 | 1000 | Mean |
| 1 | Azoxystrobin 23% SC | 88.11 (69.84) | 96.02 (78.52) | 96.98 (80.00) | 93.70 |
| 2 | Carbendazim 50% WP | 93.81 (75.60) | 98.37 (82.77) | 100.00 (90.00) | 97.39 |
| 3 | Difenconazole 25.0% EC | 94.70 (76.69) | 97.72 (81.34) | 100.00 (90.00) | 97.47 |
| 4 | Hexaconazole 5% EC | 88.74 (70.41) | 91.53 (73.08) | 93.47 (75.20) | 91.25 |
| 5 | Kresoxim methyl 44.3% SC | 94.73 (76.73) | 97.56 (81.03) | 100.00 (90.00) | 97.43 |
| 6 | Propiconazole 25% EC | 97.68 (81.28) | 98.56 (83.15) | 99.76 (88.38) | 98.67 |
| 7 | Tebuconazole 25.9% EC | 92.57 (74.19) | 97.36 (80.66) | 98.97 (85.26) | 96.30 |
| | Mean | 92.91 | 96.73 | 98.45 | |
| | | F | C | F×C | |
| | S.Em± | 0.43 | 0.28 | 0.74 | |
| | CD @ 0.01 | 1.23 | 0.81 | 2.13 | |

*Values in the parenthesis are arc sine transformed

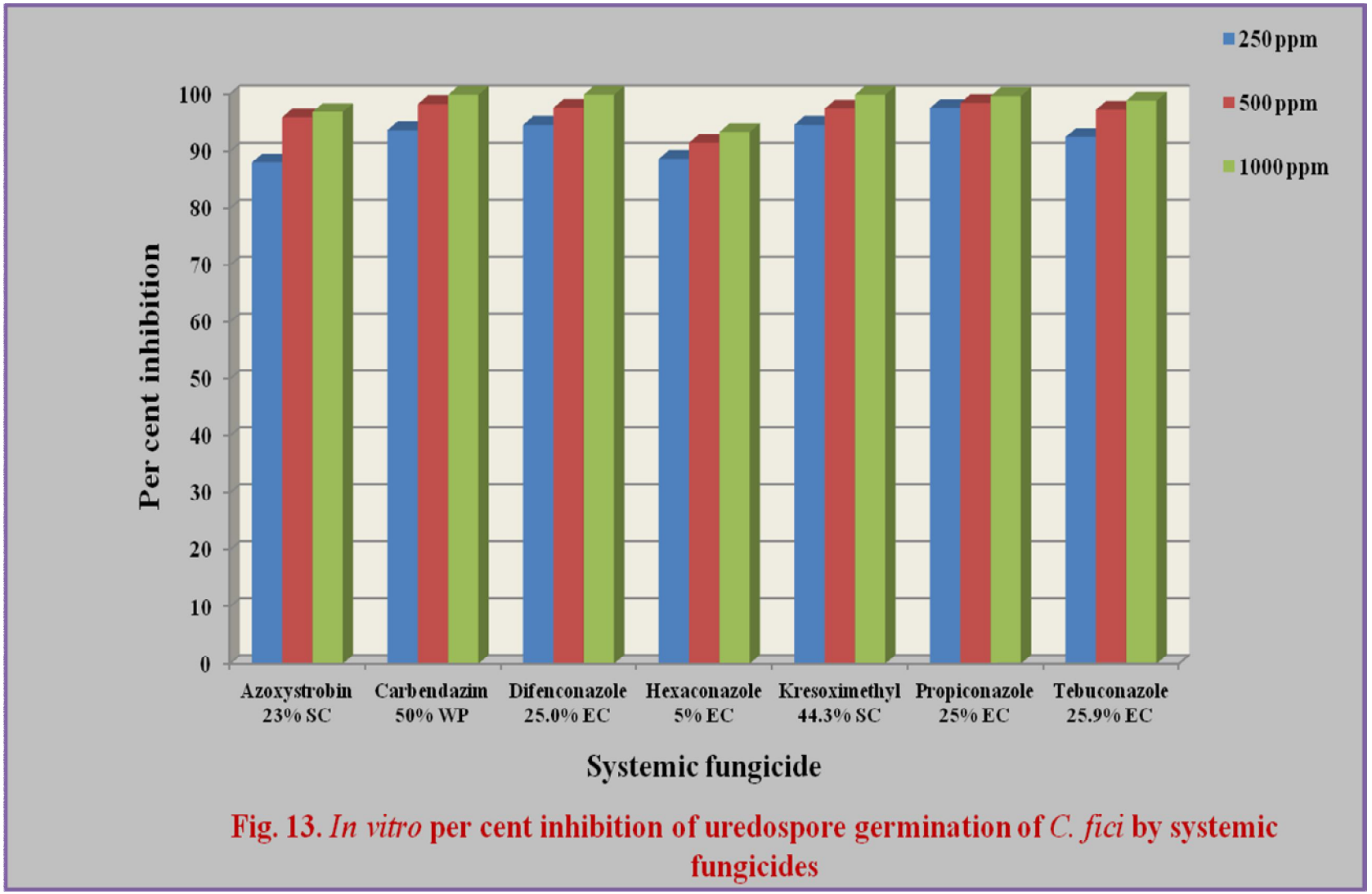



**Fig. 13. *In vitro* per cent inhibition of uredospore germination of *C. fici* by systemic fungicides**

**Table 21b. *In vitro* per cent inhibition of uredospore germination by non systemic fungicides**

| Sl. No. | Treatment | Per cent inhibition of uredospore germination | | | | Mean |
|---|---|---|---|---|---|---|
| | | Concentration (ppm) | | | | |
| | | 500 | 1000 | 2500 | 3000 | |
| 1 | Copper oxychloride 50 WP | 92.80 (74.45) | 97.19 (80.40) | 100.00 (90.00) | 100.00 (90.00) | 97.50 |
| 2 | Chlorothalonil 75 WP | 91.77 (73.34) | 95.79 (78.17) | 98.17 (82.28) | 100.00 (90.00) | 96..43 |
| 3 | Copper hydroxide 35 WG | 92.87 (74.52) | 93.37 (75.09) | 100.00 (90.00) | 100.00 (90.00) | 96.56 |
| 4 | Mancozeb 75 WP | 94.79 (76.81) | 98.36 (82.66) | 100.00 (90.00) | 100.00 (90.00) | 98.29 |
| 5 | Zineb 75 WP | 92.73 (74.36) | 96.08 (78.61) | 99.76 (88.38) | 100.00 (90.00) | 97.14 |
| | Mean | 92.99 | 96.16 | 99.59 | 100.00 | |
| | | F | C | F ×C | | |
| S.Em± | | 0.25 | 0.23 | 0.51 | | |
| CD @ 0.01 | | 0.74 | 0.66 | 1.47 | | |

*Values in the parenthesis are arc sine transformed

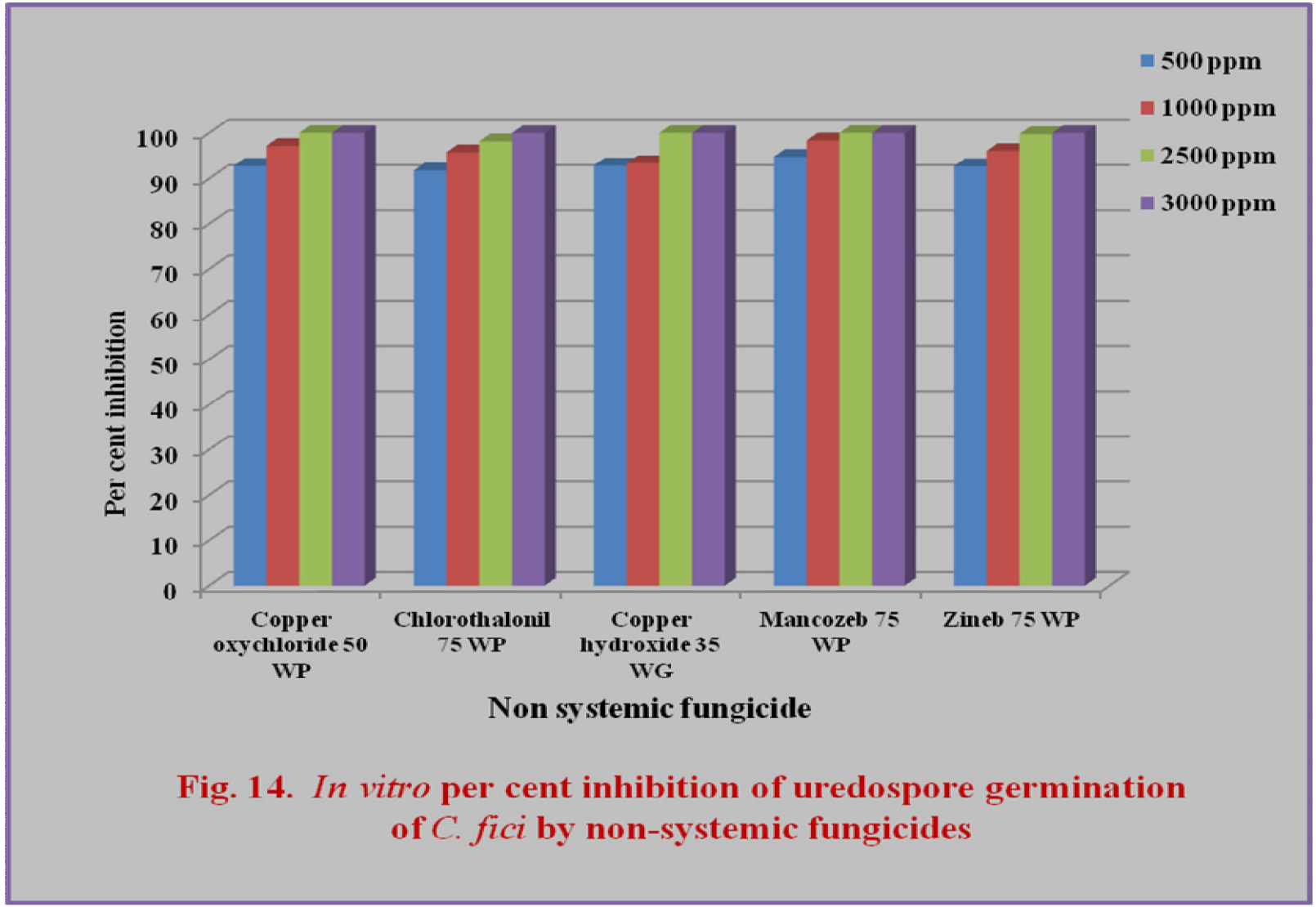



**Fig. 14. *In vitro* per cent inhibition of uredospore germination of *C. fici* by non-systemic fungicides**

at 3000 ppm, all the fungicides tested were on par with each other and gave cent per cent inhibition of spore germination. At 2500 ppm, copper oxychloride, copper hydroxide and mancozeb gave 100 per cent inhibition whereas zineb and chlorothalonil gave 99.76 and 98.17 per inhibition respectively and were significantly different from each other (Table 21b).

Along with systemic and non systemic fungicides, three combi fungicides were also tested for their efficacy to inhibit the uredospore germination. The results showed (Table 21c and Fig. 15) that at 500 ppm, tebuconazole + trifloxystrobin gave maximum inhibition (96.99%) and found to be significantly superior, followed by captan + hexaconazole (94.80%). Least inhibition was recorded in carbendazim + mancozeb (85.47%). At 1000 ppm, 100 per cent inhibition was observed in tebuconazole + trifloxystrobin whereas the other two combi fungicides captan + hexaconazole and carbendazim + mancozeb showed 97.33 and 92.30 per cent inhibition and were statistically different. At 2500 ppm, except carbendazim + mancozeb (97.32%), the other two fungicides gave 100 per cent inhibition. At the maximum concentration tested (2000 ppm), all the three fungicides found to be effective which showed 100 per cent inhibition of spore germination.

In general, it was observed that as the concentration increased, the per cent inhibition of uredospore germination also increased in all evaluated fungicides.

#### 4.6.1.2 *In vitro* evaluation of biorationals

The observations regarding inhibition of uredospore germination presented in Table 22 and Fig. 16 showed that the treatment differences due to plant extracts, amrut pani and crude oils, their concentrations and their interactions were statistically significant.

The data revealed that there was no germination of uredospores in the treatment with neem oil, safflower oil and amrut pani at all the concentrations tested and showed cent per cent inhibition and were significantly superior over other treatments. The next best treatment was coconut oil which showed 96.39 per cent spore inhibition at 5 per cent concentration and on par with ginger rhizome extract (96.02%), the next best treatement found was garlic bulb extract (86.23%). The least inhibition was observed in neem leaf extract (12.61%), tulasi leaf extract (14.83%)

**Table 21c. *In vitro* per cent inhibition of uredospore germination by fungicide combinations**

| Sl. No. | Treatment | Per cent inhibition of spore germination | | | | Mean |
|---|---|---|---|---|---|---|
| | | Concentration (ppm) | | | | |
| | | 500 | 1000 | 1500 | 2000 | |
| 1 | Captan 70% + Hexaconazole 5% WP | 94.80 (76.07) | 97.33 (80.69) | 100.00 (90.00) | 100.00 (90.00) | 97.88 |
| 2 | Tebuconazole 50% + Trifloxystrobin 25%WG | 96.99 (80.01) | 100.00 (90.00) | 100.00 (90.00) | 100.00 (90.00) | 99.25 |
| 3 | Carbendazim 12% + Mancozeb 63% WP | 85.47 (67.59) | 92.30 (73.89) | 97.32 (80.81) | 100 (90.00) | 93.77 |
| Mean | | 92.21 | 96.54 | 99.10 | 100 | |
| | | F | C | F × C | | |
| S. Em± | | 0.26 | 0.30 | 0.52 | | |
| CD @ 0.01 | | 0.77 | 0.89 | 1.54 | | |

* Values in the parenthesis are arc sine transformed

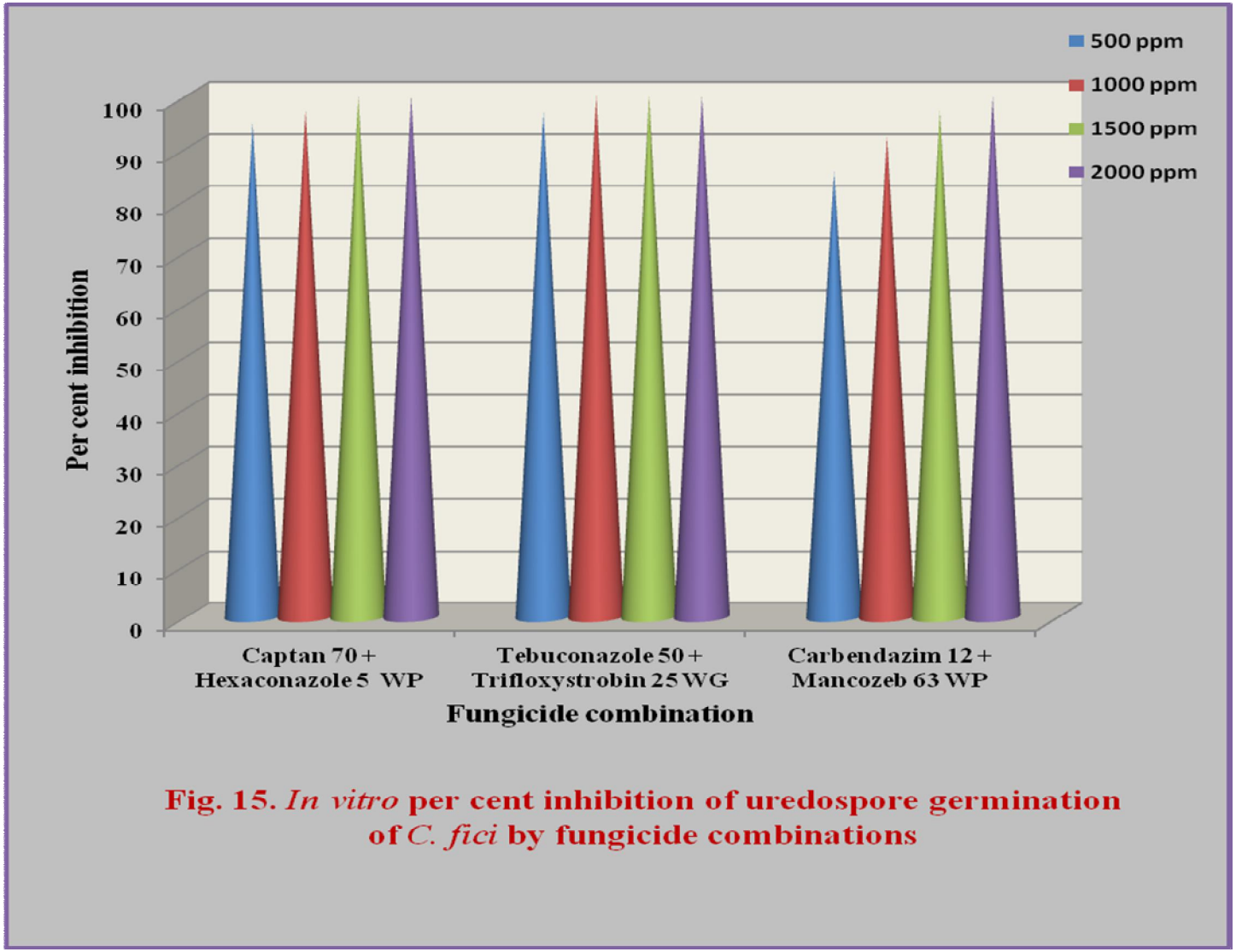



**Fig. 15. *In vitro* per cent inhibition of uredospore germination of *C. fici* by fungicide combinations**

**Table 22. *In vitro* per cent inhibition of uredospore germination by biorationals**

| Sl. No. | Treatment | Per cent inhibition | | | |
|---|---|---|---|---|---|
| | | Concentration (%) | | | |
| | | 5 | 10 | 15 | Mean |
| 1 | Castor leaf extract | 33.23 (35.20) | 41.40 (40.05) | 68.75 (56.01) | 47.79 |
| 2 | Catharanthus leaf extract | 0.00 (5.74) | 0.00 (5.74) | 0.00 (5.74) | 0.00 |
| 3 | Datura leaf extract | 44.95 (42.10) | 72.44 (58.33) | 77.01 (61.35) | 64.80 |
| 4 | Garlic bulb extract | 86.23 (68.23) | 92.06 (73.66) | 92.59 (74.21) | 90.29 |
| 5 | Ginger rhizome extract | 96.02 (78.53) | 97.50 (80.92) | 100.00 (90.00) | 97.84 |
| 6 | Lantana leaf extract | 77.27 (61.53) | 85.16 (67.35) | 92.80 (74.45) | 85.08 |
| 7 | Neem leaf extract | 12.61 (20.80) | 23.00 (28.66) | 59.05 (50.22) | 31.56 |
| 8 | Neem seed kernel extract (NSKE) | 15.32 (23.04) | 37.31 (37.65) | 40.65 (39.61) | 31.09 |
| 9 | Tulasi leaf extract | 14.83 (22.64) | 22.76 (28.49) | 36.90 (37.41) | 24.83 |
| 10 | Amrut pani | 100.00 (90.00) | 100.00 (90.00) | 100.00 (90.00) | 100.00 |
| 11 | Neem oil | 100.00 (90.00) | 100.00 (90.00) | 100.00 (90.00) | 100.00 |
| 12 | Coconut oil | 96.39 (79.07) | 100 (90.00) | 100 (90.00) | 98.80 |
| 13 | Safflower oil | 100.00 (90.00) | 100.00 (90.00) | 100.00 (90.00) | 100.00 |
| 14 | Control | 0.00 (5.74) | 0.00 (5.74) | 0.00 (5.74) | 0.00 |
| **Mean** | | 55.63 | 62.40 | 69.26 | |
| | | **T** | | **C** | **T×C** |
| **SEm±** | | 0.18 | | 0.08 | 0.31 |
| **CD @ 0.01** | | 0.50 | | 0.23 | 0.87 |

*Values in the parenthesis are arc sine transformed

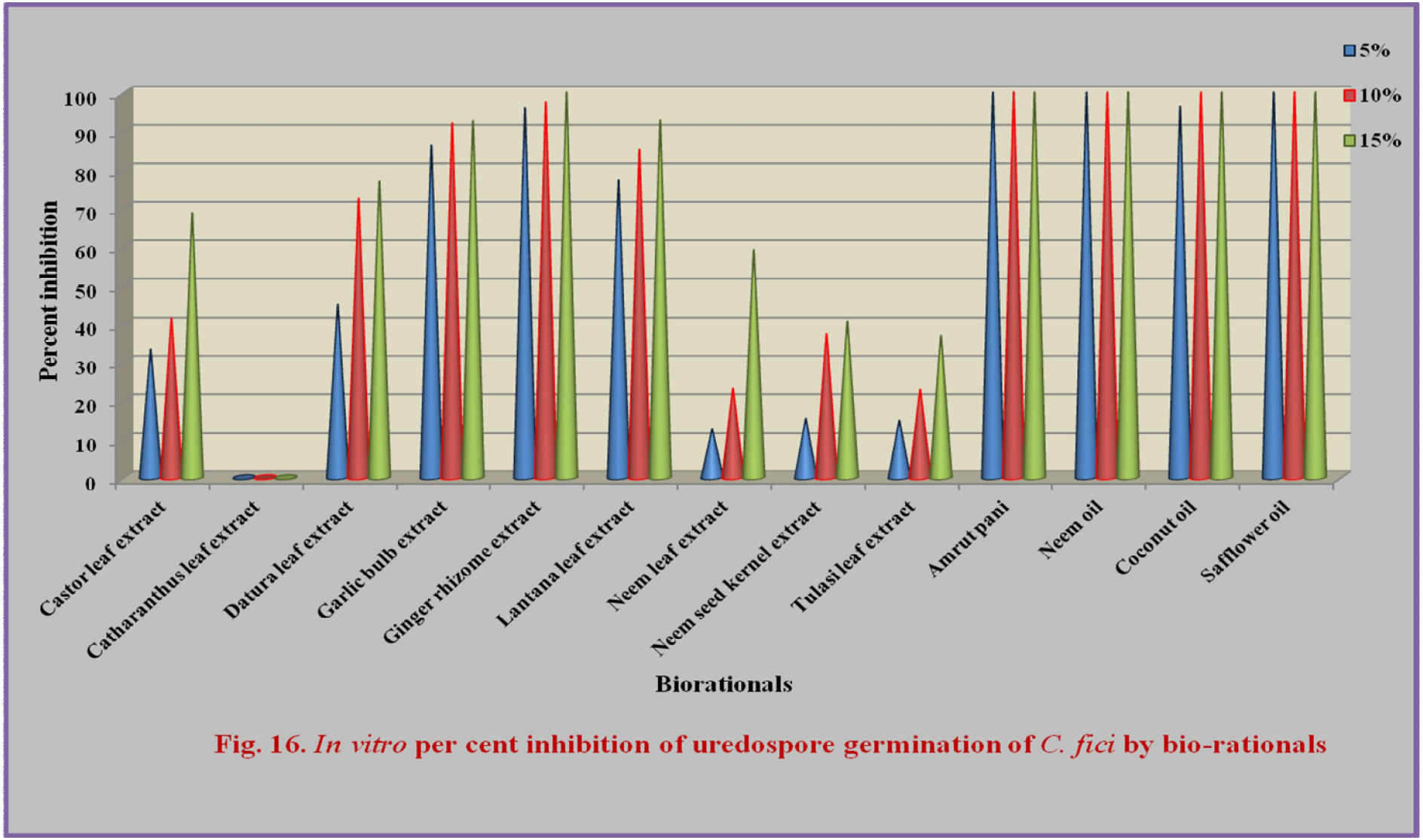



**Fig. 16. *In vitro* per cent inhibition of uredospore germination of *C. fici* by bio-rationals**

and neem seed kernel extract (15.32%) and were found to be significant. At 10 per cent concentration coconut oil, showed cent per cent inhibition, the ginger rhizome extract and garlic bulb extract were found as next best treatments by showing 97.50 and 92.06 per spore inhibition respectively. The least inhibition was showed by tulasi leaf extract (22.76%) which was on par with neem leaf extract (23.00%) followed by neem seed kernel extract (37.31%). At 15 per cent concentration tested, coconut oil and ginger rhizome extract recorded cent per cent inhibition. Lantana leaf extract (92.80) and garlic bulb extract (92.59%) on par with each other were found to inhibit urdospores more effectively at 15 per cent concentration. The least inhibition at 15 per cent concentration was recorded in tulasi leaf extract (36.90%), followed by the neem seed kernel (40.65%) extract and neem leaf extract (59.05%). At all the concentrations tested periwinkle leaf extract gave no inhibition and it was on par with control.

#### 4.6.1.3 *In vitro* evaluation of bioagents

The bioagents were evaluated as described in the 3.7.1.3. The results on per inhibition of spore germination are presented in Table 23 and Fig. 17. The results revealed that *Bacillus subtilis* and *Pseudomonas fluorescens* recorded cent per cent inhibition at all concentrations tested. The *Lecanicillium lecanii* gave 9.73, 6.17 and 3.91 per cent inhibition of uredospore germination at $1\times10^4$, $1\times10^3$ and $1\times10^2$ respectively. The treatments were found to be statistically significant.

### 4.6.2 Field management of fig rust caused by *C. fici*

#### 4.6.2.1 Effect of biorationals and bioagents on fig rust disease severity

The results on the effect of biorationals and bioagents on fig rust disease severity is presented in the Table 24 and Fig. 18. The results revealed that Ginger rhizome extract at 15 per cent concentration (60.30) recorded highest per cent reduction over control in which 49.96 and 19.80 PDI was observed five days after 1$^{st}$ and 2$^{nd}$ spray respectively and was significantly superior over other treatments. The next best treatment which recorded maximum disease reduction over control was neem oil at 5 per cent concentration (46.31 %). The garlic bulb extract at 15 per cent concentration (2.86%) recorded least per cent reduction over control. When we consider the cumulative per cent reduction of two sprays the garlic bulb

**Table 23. *In vitro* inhibition of uredospore germination by biocontrol agents**

| Sl. No. | Treatement | Per cent germination | Mean inhibition (%) |
|---|---|---|---|
| 1 | *Bacillus subtilis* ($10^5$ cfu) | 0.00 | 100.00 (90.00) |
| 2 | *Bacillus subtilis* ($10^6$ cfu) | 0.00 | 100.00 (90.00) |
| 3 | *Bacillus subtilis* ($10^7$ cfu) | 0.00 | 100.00 (90.00) |
| 4 | *Pseudomonas fluorescens* ($10^5$ cfu) | 0.00 | 100.00 (90.00) |
| 5 | *Pseudomonas fluorescens* ($10^6$ cfu) | 0.00 | 100.00 (90.00) |
| 6 | *Pseudomonas fluorescens* ($10^7$ cfu) | 0.00 | 100.00 (90.00) |
| 7 | *Lecanicillium lecanii* ($1\times10^2$ cfu) | 47.32 | 3.91 (11.39) |
| 8 | *Lecanicillium lecanii* ($1\times10^3$ cfu) | 46.21 | 6.17 (14.38) |
| 9 | *Lecanicillium lecanii* ($1\times10^4$ cfu) | 44.45 | 9.73 (18.17) |
| | Control | 49.25 | - |
| | S.Em± | | 0.10 |
| | CD @ 0.01 | | 0.38 |

*Values in the parenthesis are arc sine transformed

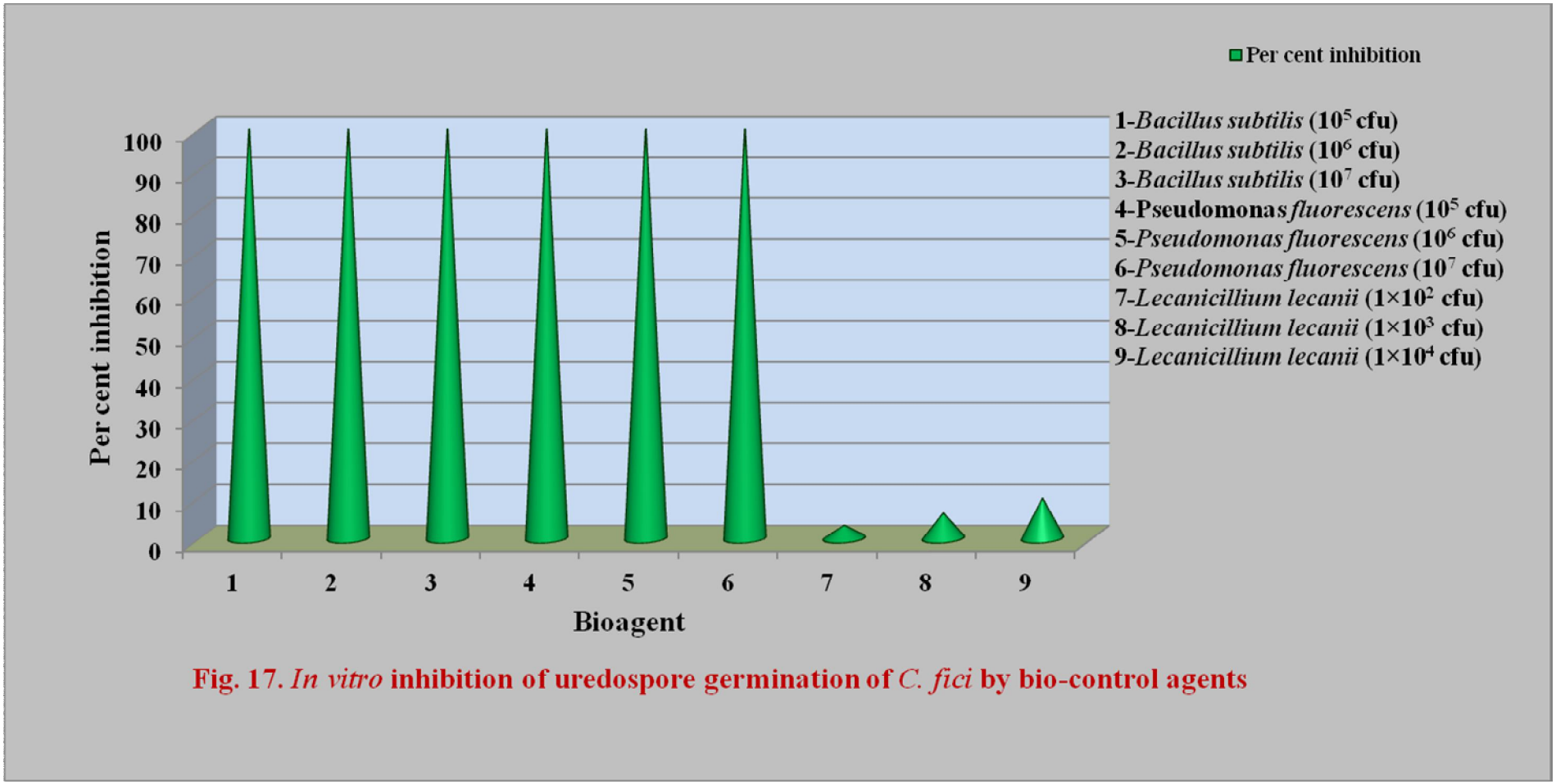



**Fig. 17. *In vitro* inhibition of uredospore germination of *C. fici* by bio-control agents**

**Table 24. Effect of biorationals and bioagents on the Per cent Disease Index (PDI) of fig rust disease caused by *C. fici* in the field conditions**

| Sl. No. | Treatment details | Per cent Disease Index (PDI) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Before spray | 5 days after 1st Spray | Per cent disease reduction after 1st spray | 5 days after 2nd spray | Per cent disease reduction after 2nd spray | Per cent disease reduction over control | Cumulative per cent reduction of two sprays |
| 1 | Amrut pani @ 5 % | 46.69 | 36.02 (36.85) | 10.67 | 32.23 (34.55) | 3.69 | 35.38 | 14.36 |
| 2 | *Bacillus subtilis* @ 0.6% | 56.26 | 43.32 (41.13) | 12.94 | 30.33 (33.37) | 12.99 | 39.19 | 25.93 |
| 3 | Garlic bulb extract @15% | 56.01 | 34.63 (36.00) | 21.38 | 48.45 (44.40) | 13.82 | 2.86 | 34.66 |
| 4 | Ginger rhizome extract @15% | 47.30 | 49.96 (44.98) | -2.60 | 19.80 (26.40) | 30.16 | 60.30 | 27.56 |
| 5 | *Lecanicillium lecanii* @ 0.6% | 55.07 | 37.17 (37.53) | 17.90 | 33.87 (35.58) | 3.30 | 32.09 | 21.20 |
| 6 | Neem oil @ 5% | 51.24 | 32.35 (34.66) | 18.89 | 26.78 (31.14) | 5.57 | 46.31 | 24.46 |
| 7 | Safflower oil @ 5% | 47.20 | 33.74 (35.48) | 13.46 | 30.21 (33.23) | 3.53 | 39.43 | 16.99 |
| 8 | Control (Water spray) | 42.52 | 44.80 (42.00) | -2.28 | 49.88 (44.93) | -5.08 | | -7.36 |
| | S.Em± | | 1.38 | | 1.32 | | | |
| | CD @ 0.05 | | 4.18 | | 4.00 | | | |

*Values in the parenthesis are arc sine transformed

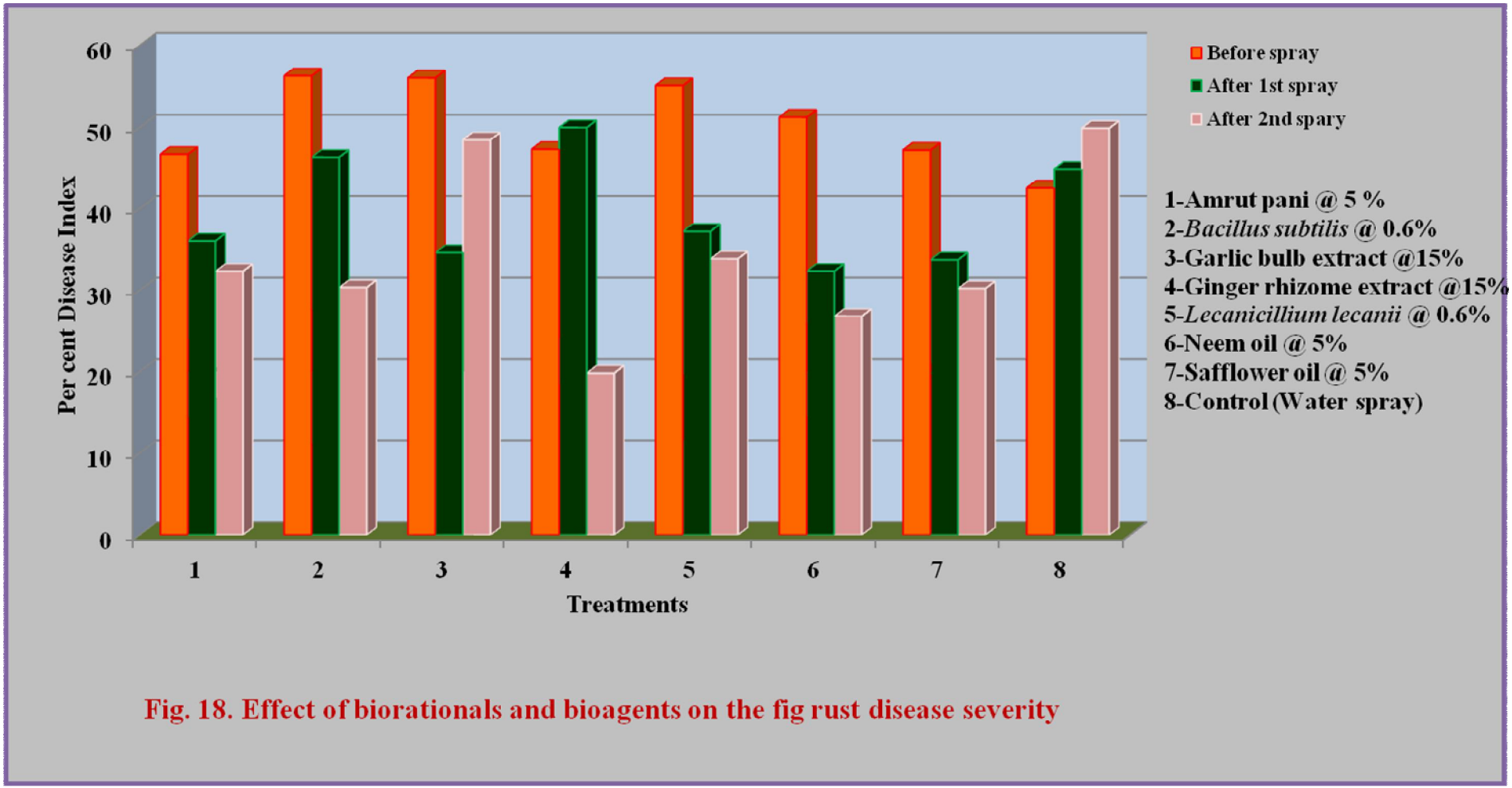



Fig. 18. Effect of biorationals and bioagents on the fig rust disease severity

extract at 15 per cent concentration (34.66%) was found to be most effective, followed by ginger rhizome extract at 15 per cent concentration (27.56%) and *Bacillus subtilis* (Milastin @ 6%) (25.93%). The least cumulative per cent reduction of two sprays was observed in amrut pan at 5 per cent concentration (14.36%).

**4.6.2.2 Field management of rust disease through fungicides**

**4.6.2.2.1 Effect of fungicides on rust disease severity**

The plants were scored for the disease severity, five days after each spray and the data pertaining to effect of fungicides on rust disease severity is presented in the Table 25 and Fig. 19.

After the 1st spray, the lowest PDI was observed in the treatment, 0.1 per cent difenconazole (30.37), followed by 0.1 per cent tebuconazole (31.11) and 0.25 per cent mancozeb (33.09) and were on par with each other. The control (42.47) recorded the highest PDI when compared to the fungicidal treatments.

After 2nd spray, 0.25 per cent mancozeb (25.06) recorded lowest PDI and was significantly superior over other treatments, followed by 0.1 per cent hexaconazole (36.05). The highest PDI was observed in control (45.68).

After 3rd spray, lowest PDI was recorded in 0.25 per cent mancozeb (37.53) and 0.1 per cent hexaconazole (37.53) which were superior over other treatments followed by 0.1 per cent tebuconazole (42.02), 0.1 per cent propiconazole (42.22), 0.1 per cent kresoxim methyl (43.12) and 0.1 per cent difenconazole (43.46) which were on par with each other. The control (53.83) treatment recorded highest PDI.

After 4th spray, 0.1 per cent tebuconazole (31.85) recorded least PDI and is significantly superior over other treatments followed by 0.1 per cent propiconazole (35.06) and 0.25 per cent mancozeb (35.56) which were on par with each other. The highest PDI was recorded in control (59.26), which was significantly different from other treatments followed by 0.1 per cent azoxystrobin (54.32).

The maximum per cent disease reduction over control was observed in 0.1 per cent tebuconazole (46.25%) followed by 0.1 per cent propiconazole (40.84%) and 0.25 per cent mancozeb (39.99%) (Plate 8). The minimum per cent disease reduction

**Table 25: Effect of fungicide molecules on development of fig rust severity**

| Sl. No. | Treatment | Per cent disease severity | | | | | Per cent disease reduction over control after 4th spray |
|---|---|---|---|---|---|---|---|
| | | Before spray | After 1st spray | After 2nd spray | After 3rd spray | After 4th spray | |
| 1 | Azoxystrobin 23% SC @ 0.1% | 31.70 | 37.04 (37.45) | 44.94 (42.09) | 47.41 (43.51) | 54.32 (47.48) | 8.34 |
| 2 | Captan 70% + Hexaconazole 5% @ 0.1% | 36.25 | 37.53 (37.78) | 38.27 (38.21) | 49.63 (44.79) | 53.83 (47.20) | 9.16 |
| 3 | Carbendazim 50% WP @ 0.1% | 32.45 | 36.05 (36.87) | 37.78 (37.89) | 51.86 (46.06) | 47.90 (43.80) | 19.17 |
| 4 | Difenconazole 25.0% EC @ 0.1% | 29.40 | 30.37 (33.41) | 39.75 (39.02) | 43.46 (41.23) | 40.74 (39.66) | 31.25 |
| 5 | Hexaconazole 5% EC @ 1% | 31.28 | 34.81 (36.16) | 36.05 (36.90) | 37.53 (37.78) | 40.99 (39.80) | 30.83 |
| 6 | Kreoxim methyl 44.3% w/w @ 0.1% | 31.26 | 35.56 (36.57) | 37.78 (37.92) | 43.12 (41.04) | 43.21 (41.09) | 27.08 |
| 7 | Mancozeb 75% WP @ 0.25% | 31.25 | 33.09 (35.11) | 25.06 (30.03) | 37.53 (37.78) | 35.56 (36.60) | 39.99 |
| 8 | Propiconazole 25.0 % EC @ 0.1% | 35.43 | 38.52 (38.36) | 38.77 (38.40) | 42.22 (40.46) | 35.06 (36.29) | 40.84 |
| 9 | Tebuconazole 25.9% EC @ 0.1% | 31.10 | 31.11 (33.89) | 39.01 (38.64) | 42.02 (40.32) | 31.85 (34.36) | 46.25 |
| 10 | Control (water spray) | 33.37 | 42.47 (40.67) | 45.68 (42.52) | 53.83 (47.60) | 59.26 (50.35) | |
| S. Em± | | | 2.44 | 1.75 | 1.47 | 1.00 | |
| CD @ 0.05 | | | 7.27 | 5.21 | 4.39 | 2.98 | |

*Values in the parenthesis are arc sine transformed

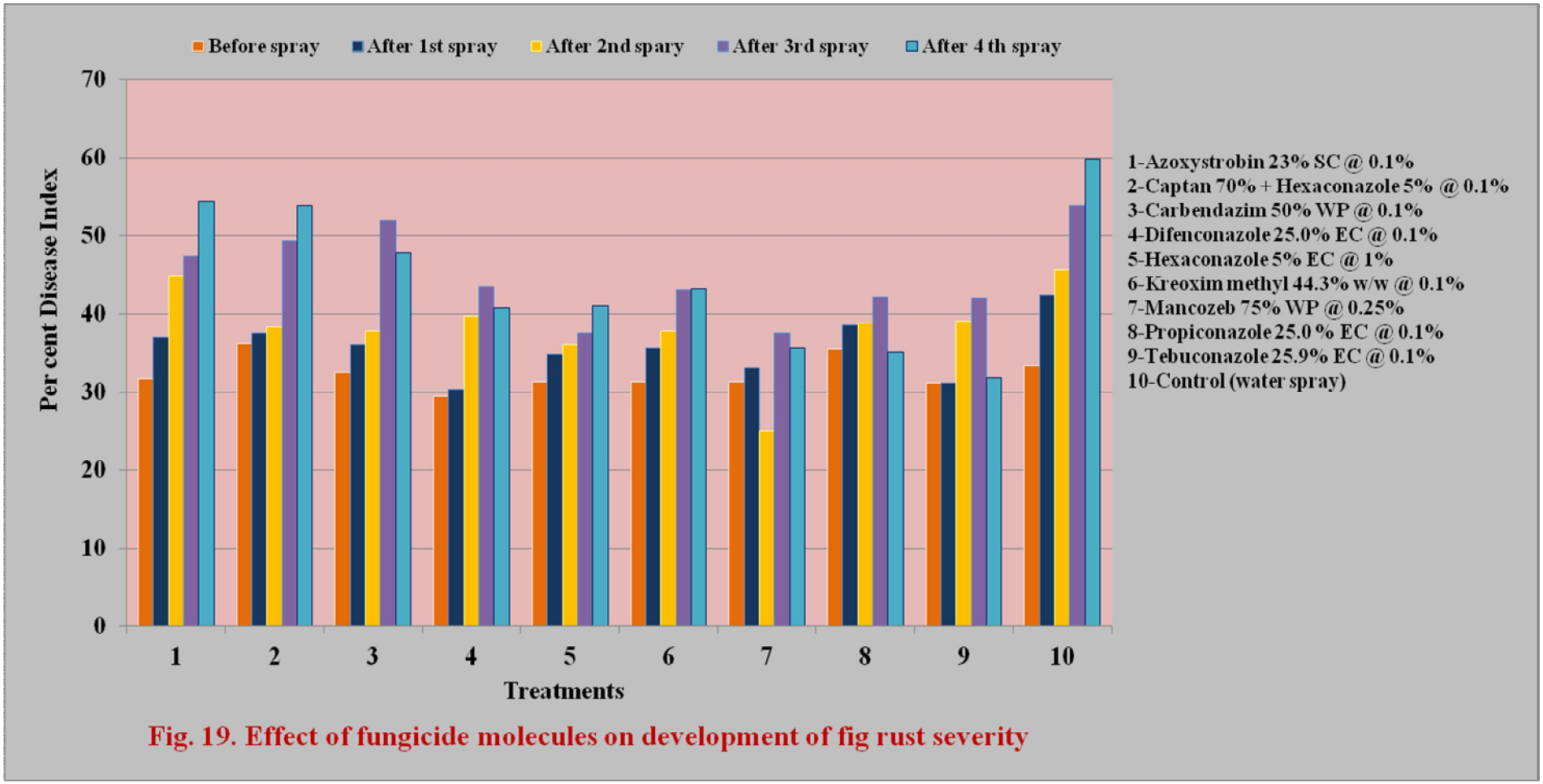



**Fig. 19. Effect of fungicide molecules on development of fig rust severity**



General field view




$T_8$-Tebuconazole 0.1 per cent



$T_7$-Mancozeb 0.25 per cent

**Plate 8. Field evaluation of fungicides**

over control was recorded in 0.1 per cent azoxystrobin (8.34%) followed by 0.1 per cent capatan + hexaconazole (1.62%).

#### 4.7.2.2.2 Effect of fungicides on the yield parameters

The data regarding yield parameters, monetary returns and benefit cost ratio is described in the Table 26.

**Number of fruits per plant**

The highest number of fruits per plant was recorded in 0.1 per cent tebuconazole (205.67) which was significantly superior over other treatments, followed by 0.1 per cent propiconazole (190.33) and 0.25 per cent mancozeb (186.33) which were on par with each other. The lowest number of fruit was observed in control (74.33) which was on par with 0.1 per cent captan + hexaconazole (75.67) and 0.1 per cent azoxystrobin (80.67).

**Fruit yield per plant (Kg plant$^{-1}$)**

The highest fruit yield per plant was observed in 0.1 per cent tebuconazole (8.32 Kg plant$^{-1}$) which was on par with 0.1 per cent propiconazole (7.71 Kg plant$^{-1}$) The lowest fruit yield per plant was observed in control (2.23 Kg plant$^{-1}$) on par with 0.1 per cent captan + hexaconazole (2.64 Kg plant$^{-1}$) and 0.1 per cent azoxystrobin (2.79 Kg plant$^{-1}$).

**Yield per hectare (t ha$^{-1}$)**

Treatment 9, 0.1 per cent tebuconazole (5.54 t ha$^{-1}$) recorded the highest fruit yield followed by 0.1 per cent propiconazole (5.13 t ha$^{-1}$) which were on par with each other and 0.25 per cent mancozeb (4.56 t ha$^{-1}$) on par with 0.1 per cent hexaconazole (4.05 t ha$^{-1}$). The lowest yield was recorded in control (1.65 t ha$^{-1}$) which was on par with 0.1 per cent captan + hexaconazole (1.76 t ha$^{-1}$) and 0.1 per cent azoxystrobin (1.86 t ha$^{-1}$).

**Influence of fungicide spray on total monetary returns**

The highest net returns was recorded in 0.1 per cent tebuconazole (165366 Rs/ha), followed by 0.1 per cent propiconazole (151320 Rs/ha) and 0.25 per cent

**Table 26: Effect of fungicides on fig yield parameters and benefit cost ratio**

| Sl. No. | Treatments Details | No. of fruits/plant | Fruit yield (kg/plant) | Fruit yield (Ton/ha) | Cost of Cultivation (Rs/ha) | Cost of fungicide (Rs/ha) | Total cost (Rs/ha) | Gross Returns (Rs/ha) | Net Returns (Rs/ha) | BC ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Azoxystrobin 23% SC @ 0.1% | 80.67 | 2.79 | 1.86 | 49450 | 16542 | 65992 | 74378 | 8387 | 1.13 |
| 2 | Captan 70% + Hexaconazole 5% @ 0.1% | 75.67 | 2.64 | 1.76 | 49450 | 4322 | 53772 | 70349 | 16577 | 1.31 |
| 3 | Carbendazim 50% WP @ 0.1% | 90.33 | 3.53 | 2.35 | 49450 | 4402 | 53852 | 93977 | 40124 | 1.75 |
| 4 | Difenconazole 25.0% EC @ 0.1% | 161.33 | 4.74 | 3.16 | 49450 | 13073 | 62523 | 126324 | 63801 | 2.02 |
| 5 | Hexaconazole 5 EC @ 1% | 152.67 | 6.09 | 4.05 | 49450 | 1809 | 51259 | 162125 | 110866 | 3.16 |
| 6 | Kreoxim methyl 44.3% w/w @ 0.1% | 115.33 | 4.44 | 2.96 | 49450 | 3447 | 52897 | 118291 | 65394 | 2.24 |
| 7 | Mancozeb 75% WP @ 0.25% | 186.33 | 6.85 | 4.56 | 49450 | 3202 | 52652 | 182469 | 129817 | 3.47 |
| 8 | Propiconazole 25.0 % EC @ 0.1% | 190.33 | 7.71 | 5.13 | 49450 | 4536 | 53986 | 205305 | 151320 | 3.80 |
| 9 | Tebuconazole 25.9% EC @ 0.1% | 205.67 | 8.32 | 5.54 | 49450 | 6750 | 56200 | 221566 | 165366 | 3.94 |
| 10 | Control (Water spray) | 74.33 | 2.23 | 1.65 | 49450 | - | 49450 | 66000 | 16550 | 1.33 |
| | S.Em± | 2.30 | 0.33 | 0.22 | | | | | | |
| | CD @ 0.05 | 6.32 | 0.97 | 0.64 | | | | | | |

mancozeb (129817 Rs/ha). The lowest net returns was recorded in 0.1 per cent azoxystrobin (8387 Rs/ha) followed by control (16550 Rs/ha) and 0.1 per cent captan + hexaconazole (16577 Rs/ha).

The highest BC ratio was observed in 0.1 per cent tebuconazole (3.94) followed by 0.1 per cent propiconazole (3.80) and 0.25 per cent mancozeb (3.47). The lowest BC ratio was observed in 0.1 per cent azoxystrobin (1.13) followed by 0.1 per cent captan + hexaconazole (1.31) and control (1.33).

# 5. DISCUSSION

The Fig is always fascinating to the man kind and is found to be the oldest fruit being the important deciduous crop. The fruit is consumed as fresh or dried. It is processed in to various products and is always prized for its nutritional importance. Though the crop is found to be tolerant to a wide range of climatic conditions, the yield and returns from this crop is highly discounted due to some of the important pest and diseases. Among which the rust disease caused by *C. fici* is the most important fungal disease. The severe disease incidence causes more than 50 per cent yield losses.

At present, the disease has become a major limiting factor in the fig cultivation. This disease is present in all the fig growing regions and is described as endemic to all the fig growing regions. This disease has limited the farmers income and the quality of produce which prompted us to carry out the current research on the disease in which we were committed to survey the major fig growing regions of North Karnataka, optimising of spore germination conditions, screening of fig varieties and *in vitro* and *in vivo* evaluation of fungicides, botanicals and bioagents for the effective management of the disease.

## 5.1 Symptomatology

The fig rust disease symptoms were studied in the natural epiphytotic conditions at Fruit orchard, UHS, Bagalkot. The disease affected most of the plant parts except roots like leaves, petioles, shoots and fruits. The leaves were found as severely rusted plant parts. The upper leaves at the tip of the shoot remained free from the disease. The lower leaves showed prominent rust symptoms. The same results were also reported by Kumar and Khurana (2015) and Baiyewu *et al.* (2005) that apical buds of *Ficus benjamina* were free from infection and matured leaves were highly susceptible to the rust disease in mulberry crop respectively.

The symptoms first appeared as small, elongated yellowish spots or flecks visible on adaxial surface of the leaf consequently brownish pustules developed on the corresponding abaxial surface. Mckenzie (1986), Kumar and Khurana (2015) and Latinovic *et al.* (2015) has recorded the similar kind of symptoms on the *Ficus* plants

infected by *C. fici* and Baiyewu *et al.* (2005) in mulberry crop. As the disease progressed lessions covered the upper surface. Subsequently, the pustules burst opened by rupturing the epidermal wall to release the brown spore mass on the abaxial surface of the leaf. These results are in conformity with Kumar and Khurana (2015) and Baiyewu *et al.* (2005). The pustules were concentrated along the margin of the leaf blade which was also reported by Mckenezie (1986). Under severe infestation the leaves found to be twisted upward, dried and prematurely defoliated. The defoliation is due to the completion of sporulation every 20-30 days (Pastore *et al.,* 2017). The research work of Mckenezie (1986), Baiyewu *et al.* (2005) and Latinovic *et al.* (2015) on *C. fici* has shown the similar kind of results.

On petioles and shoots, the brown elongated narrow spots were observed and these spots were not erupted and uredospores were not formed. Under congenial conditions the fruits were also severely infested. The thin hand sections of the infected portion of fruit clearly showed the presence of the uredinium and uredospores. The presence of Uredina on the rusted fig fruit was also reported by Mckenezie (1986).

### 5.1.2 Spore morphology

The uredospores were appeared as dusty brown on the lower side of the leaf. The spores were found to be oblong to elongated in shape. The spores are echinulated and found to have 1-3 germpores from which germtube emerged. The results are in agreement with Mckenezie (1986).

## 5.2 Survey for fig rust severity in major fig growing regions of North Karnataka

A roving survey was conducted to know the severity of fig rust disease, during the year 2017-18, in the areas of Bagalkot, Bellary and Koppal districts of North Karnataka

The findings of the present study revealed that rust was noticed in all the locations surveyed as reported by Thirumalachar *et al.* (1950) and Philip *et al.* (1997). Overall disease severity observed in Northern Karnataka was 58.78 PDI which is in agreement with the survey conducted by Gunashekar *et al.* (1995) who has reported the high incidence of fig rust in Karnataka. The severity of the disease was more in

Ballary district (66.93 PDI) followed by koppal (64.09 PDI) and least in Bagalkot (51.46 PDI) district.

Microclimate build up due to heavy crop canopy also helps in pathogen multiplication. The highest severity of rust may be attributed to the leaf wetness, temperature and relative humidity that prevailed during the crop period which is favourable for the fig rust development and spread. The warm and humid weather favoured the disease development as reported by Latinovic *et al.* (2015).

In the present investigation the data were collected from different locations, this clearly indicated that the disease severity and development depended on factors like location, stage of the crop, cultural practices followed, susceptibility of the cultivars grown and prevailing meteorological factors like temperature, relative humidity and rainfall.

The Ballary district followed by Koppal district has recorded maximum Disease severity *i.e.*, 66.93 PDI and 64.09 PDI respectively. This is because of large area under cultivation and also the crop age. Whereas the least PDI was observed in Bagalkot district which may be due to the limited cultivated area. In all the regions surveyed Bellary is the most cultivated variety which is highly susceptible to the disease.

### 5.3 Proving Pathogenicity

The different methods of inoculation of uredospore were conducted in which all the methods were found effective in producing the maximum disease development. The spore dusting was found superior when compared with other methods of inoculation studied. This is in conformity with scientist Ramanath (2013). The latent period of 7 to 8 days was observed for all the varieties inoculated which is in common with the work of Ramanath (2013) who has reported 7 days latency period. The spray method of inoculation was found to have more latent period (9 days). The work of Kumar and Khurana (2015) also revealed the higher latency period in spray inoculation (15 days) on *Ficus benajamina*. The variety Poona was found to have low

infection followed high latent period compared with Excel and Bellary varieties. The Poona is resistant when compared with the varieties Excel and Bellary which are highly susceptible to the disease.

## 5.4 Effect of sugars, relative humidity and temperature on uredospore germination

### 5.4.1 Effect of sugars on uredospore germination

Spore germination is an essential developmental stage in the life cycle of fungi, which involves the conversion of resting or dormant spore into a rapidly growing germtube from which the mycelium will be produced and the nutrients must be taken up by the spore to initiate and to maintain the progress of germination. The constituents of substrate are known to influence spore germination of some species of fungi.

In the present investigation, uredospore germination was carried out in tap water, RO water, distilled water and the water agar (0.5%) containing sucrose (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0%) and dextrose (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0%) under laboratory conditions. The maximum spore germination was observed in 2.5 per cent sucrose followed by 2.0 per cent sucrose and 2 per cent dextrose and least spore germination in RO water as compared to distilled water and tap water.

These findings are in comparsions with Sumangala *et al.* (2014). They found that, uredospore germination of brown rust pathogen of sugar cane was maximum in sucrose at 2.0 per cent and least in 0.5 per cent sucrose.

### 5.4.2 Effect of temperature on uredospore germination

Temperature plays an important role among the physical factors, which influences distribution, growth and reproduction of the fungus. The present study revealed that the fungus showed variation in its spore germination at different temperatures. The maximum spore germination was observed at 25 ˚C. The present study has clearly showed that temperature from 15 to 25˚ C promotes the spore germination and 25˚ C is optimum to initiate the uredospore germination and beyond which the germination decreased gradually.

These findings are in agreement with Blum *et al.* (2015), Sumangala *et al.* (2014), Veena and Adiver (2015) and Dey *et al.* (2015). Doodley (1984) reported that, uredospores were killed when exposed to 30˚ C for six hr and at 35˚ C for 30 min, which might be one of reason for decrease in uredospore germination with the increasing temperature above 25˚ C.

### 5.4.3 Effect of relative humidity on uredospore germination

Similar to temperature, relative humidity is also one of the important environmental factors influencing uredospore germination. In the present investigation the maximum germination was observed at 100 per cent relative humidity followed by 90 per cent and at 65 per cent no germination was reported. This clearly shows that relative humidity is the most important physical factor which determines the infection.

The results are in conformity with the results of Doodley (1984) and Veena and Adiver (2015) and contradictory to the results of Sumangala *et al.* (2015), they reported the maximum spores germination at 85 per cent relative humidity and minimum at 65 per cent.

## 5.5 Screening of fig varieties

### 5.5.1 Screening of fig varieties for resistance to rust disease in natural epiphytotic condition

In the present investigation all the varieties tested for resistance to rust disease were found to be susceptible and no resistance was found in the varieties tested. These findings are cordial to Prakashan and Thamburaj (1991) who has reported that only Timla fig (*F. auriculata*) was immune among the fifteen accessions screened at Yercaud, Tamil Nadu and Reddy *et al.* (1997) who has rated all the six varieties of fig screened at Ananthpur, Andhra Pradesh as susceptible. The results of present study is contradictory with Srikantappa and Naik (2004) who reported that Poona was more susceptible to the disease than Bellary.

### 5.5.2 The area under disease progress curve (AUDPC) and apparent rate of infection (r values)

The area under disease progress curve can be positively correlated with the per cent disease index and negatively with resistance. The six fig varieties screened in natural epiphytotic conditions recorded the AUDPC values ranging from 2005.99 to 3207.65. The maximum was recorded in Excel and minimum in Poona. This data revealed that Poona is less susceptible to the disease compared when compared to other fig varieties. As suggested by Chand *et al.* (2006), Chattopadyay *et al.* (2014) and Draz *et al.* (2015) the variety showing lower AUDPC values can be considered as less susceptible to the disease. These results are contradictory to Sreekantappa and Naik (2004) who reported that Poona was having more AUDPC values than the variety Bellary.

The Dienna has recorded the maximum apparent rate of infection which was also found to be highly susceptible to the rust disease. But the least rate of infection was observed in Bellary (0.049), which is also highly susceptible variety. As the Hanumanth *et al.* (2015) suggested we an relay on AUDPC values rather than r value for considering the susceptibility of the varieties to the rust disease.

### 5.5.3 Environmental factors and rust development

#### 5.5.3.1 Simple linear correlation

The role of temperature, relative humidity (RH) and rainfall on rust disease severity on fig was studied under field condition during 2017-18. The disease severity varied considerably.

The disease severity on different fig varieties evaluated differed in their correlation coefficients with weather parameters which revealed that, along with weather parameters correlated, the host also had significant influence on the disease severity. In general the pooled data of correlation studies revealed that the morning relative humidity and afternoon relative humidity had significant positive correlation with the disease severity and minimum and maximum temperature was significantly negatively correlated. The rainfall had no significant relation with the disease severity and it was negatively correlated.

The results are in agreement with Tessmann *et al.* (2001), Beest *et al.* (2008) and Barerra *et al.* (2013) with regard to the temperature and had reported that temperature had maximum influence on the disease. The Ponte *et al.* (2006) in soybean rust reported that temperature had lower correlation with disease severity. The minimum temperature was also reported to have significant negative correlation with the groundnut rust disease by Kanade *et al.* (2015) which is similar to the present findings. The finds about relative humidity are in consonance with Srikantaswamy *et al.* (2006). Kanade *et al.* (2015) reported that morning relative humidity had positive correlation and the evening relative humidity had negative correlation with the rust disease severity on groundnut. The rainfall was showed to have negative correlation and had no significant correlation with the disease severity, is in consonance with Kanade *et al.* (2015).

The findings of the present investigation are contradictory to the results of Upadhyay *et al.* (2017).

Higher temperature limits the rust disease severity and the fig rust disease is favoured by warm and humid weather (Latinovic *et al.*, 2015).

#### 5.5.3.2 Regression analysis

The multiple linear regression analysis indicate that the morning relative humidity (%), afternoon relative humidity (%), minimum temperature (˚C) and maximum temperature (˚C) had significant influence on disease severity on all the varieties. These results are in confirmation with the studies conducted by Barerra *et al.* (2008) and Kanade *et al.* (2013).

### 5.5.4 Biochemical studies

**Reducing sugars**

The reducing sugar content was found to increase in all the varieties due to the rust infection. The reducing sugar content is comparatively less in the variety Poona in the healthy plant which is susceptible when compared to other varieties which were highly susceptible to the rust disease. These findings are different from the studies of the other researchers like Sunkad and Kulakarni (2006) and Ammajamma and Patil

(2008) who had reported the increase of sugars in the resistant and moderately resistant cultivars.

**Total sugars**

The total sugar content was more in the rust infected plant when compared with the healthy plant exclusively in the lower leaves on which the infection is more pronounced. This increase in total sugars is attributed to the pathogenesis. These findings are different from the studies of the other researchers like Sunkad and Kulakarni (2006) and Ammajamma and Patil (2008) who had reported the increase of sugars in the resistant and moderately resistant cultivars whereas in the present investigation on fig rust all the varieties tested were susceptible to the disease and showed increase in the sugar content upon rust infection.

**Non reducing sugars**

The findings about non reducing sugars are same as reducing and total sugars. The infected leaf showed increase in the concentration of non reducing sugars when compared to the healthy leaves.

**Total proteins**

The total protein content was found to increase in the rust infected leaves. The leaf upon infection by the rust pathogen turns to sink rather than source at the infection site. Therefore the increase was observed in the lower leaves which are more prone to the infection.. The results obtained regarding the changes in protein content are in agreement with the research findings of Arun *et al.* (2010).

**Total phenols**

Phenolic compounds are the plant secondary metabolites playing an important role in plant resistance. They are performed in response to the stress condition. In the present study the increase in the phenol content was clearly observed in all the varieties upon rust infection. The results obtained about changes in phenol content are in confirmation with Reddy (1984), Akhtar *et al.* (2011) and Kuvalekar *et al.* (2011).

**Chlorophyll content**

The chlorophyll a, chlorophyll b and total chlorophyll content of the upper leaves are less when compared to the lower leaves as they are young. The chlorophyll a, chlorophyll b and total chlorophyll content of the lower leaves of the rust infected plants were highly reduced when compared with the healthy leaves. Upon infection the epidermal cells are destroyed as the uredospores burst upon from the abaxial surface. The results of present investigation on chlorophyll content are in consonance with the findings of Ammajamma and Patil (2008).

**Epicuticular Wax**

The epicuticular wax is a preformed defense, which was more in the upper leaves compared to lower leaves, which might be one of the reason for the susceptibility of lower leaves to the rust disease. The epicuticular wax content also less in the infected leaves of all the varieties when compared to the healthy leaves. The results obtained about the wax content are in confirmation with Ebercon *et al.* (1977) and Sunkad and Kulakarni (2006).

## 5.6 Management of fig rust using fungicides, biorationals and bioagents

### 5.6.1 *In vitro* evaluation of fungicides, biorationals and bioagents

#### 5.6.1.1 *In vitro* evaluation of fungicides

In the present investigation, among the systemic fungicides tested propiconazole (98.67%), difenconazole (97.47%), kresoxim methyl (97.43%) and carbendazim (97.39%) were found as highly effective at all the concentrations tested. Whereas, among the non systemic fungicides tested mancozeb (98.29%) was found to inhibit the spore germination effectively. The trifloxystrobin+tebuconazole (99.25%) was found as highly effective against spore germination at all the concentrations tested.

These results are in comparsion with Amaresh and Nargund (2003) and Kalppanavar *et al.* (2008) who has reported the efficacy of propiconazole at lower concentrations against spore germination. Chaudhary and Chaudhari (2013) also reported the efficacy of propiconazole and the non systemic fungicide mancozeb in inhibition of uredospore germination. Dey *et al.* (2013) found tebuconazole as

effective at different concentrations tested and mancozeb among the non systemic fungicides.

#### 5.6.1.2 *In vitro* evaluation of biorationals

The plant extracts are known for their antimicrobial properties. Therefore they can be effectively utilized against the phyto pathogens.

In the present investigation, neem oil (100.00%), safflower oil (100.00%), amrut pani (100.00%), ginger rhizome extract (97.84%), coconut oil (98.80%) and garlic bulb extract (90.29%) were found to be highly effective at all the concentrations tested. Azadirachtin, active ingredient of neem oil is fungicidal which might have involved in inhibiting the uredospore germination. The ginger and garlic are known for their anti microbial activity since the time immemorial. The active ingredients like gingerol in ginger and allicin (a sulphur compound) in garlic and may be other components present may have reduced the uredospore germination. These results are in conformation with Chaudhary and Chaudhari (2013) who has reported the maximum inhibition of uredospore germination in garlic bulb extract, followed by onion bulb eaxtract and ginger rhizome extract. These findings are in consonance with Dey *et al.* (2013) and Shabana *et al.* (2017).

The present study are not in conformation with respect to neem leaf extract and neem seed extract as reported by other scientists like Hundekar (1999), Zade *et al.* (2005), Subramani *et al.* (2012) and Veena *et al.* (2016). Zade *et al.* (2005) also reported the efficacy of sadhaphuli (perwinkle) leaf extract against *Puccinia archadis* and not confirmed in the present study.

#### 5.6.1.3 *In vitro* evaluation of bio control agents

In the present investigation, the bioagent *Bacillus subtilis* and *Pseudomonas fluoroscens* gave cent per cent inhibition at all the concentrations tested. These results are in comaprsion with Dey *et al.* (2013), Navilker and Narayanaswamy (2015) and Marwa and Hassan (2012) in which they reported the efficacy of bacterial bioagents in reducing the uredospore germination. The bacterial bioagents produce the

metabolites having antagonistic effect on the other microbes which may have involved in reducing the uredospore germination.

The *Lecanicillium lecanii* recorded least uredospore inhibition compared to bacterial bio agents. The *L. lecanii* is parasitic on rust fungi. These results are in comparison with Sultana *et al.* (2000) and Mehafud *et al.* (2006).

### 5.6.2 Field management of fig rust caused by *C. fici*

#### 5.6.2.1 Effect of biorationals and bioagents on fig rust disease severity

All the treatments have effectively reduced the disease severity. Among the different treatments ginger rhizome extract at 15 per cent, neem oil and safflower oil at 5 per cent and garlic bulb extract at 15 per cent, effectively reduced the disease severity. The bioagents *viz.*, *B. subtilis* (0.6%) and *L. lecanii* (0.6%) have reduced the disease severity significantly.

These findings about biorationals are in comparsion with Ganapathy and Narayanswamy (1990) and Kamble and Patil (2017).The findings on *Lecanicillium lecanii* are in comparsion with Subramanyam *et al.* (1990) and Mehfud *et al.* (2006) who had reported the parasitizing nature of the fungi and Sheroz *et al.* (2003) who had reported the reduction in pustule development in coffee rust.

Leifert *et al.* (1995) has reported that the antibiotic production as the mode of action of *B. subtilis* against *Botytis cinerea*. The results of present investigation are in consonance with Yuen *et al.* (2001) and Marwa and Hassan (2017) also.

#### 5.6.2.2 Field management of rust disease through fungicides

##### 5.6.2.2.1 Effect of fungicides on rust disease severity

In the field condition the fungicides *viz.*, 0.1 per cent tebuconazole (46.25%), 0.1 per cent propiconazole (40.84%), 0.25 per cent mancozeb (39.99%) and 0.1 per cent difenconazole (31.25%) were found highly effective as they gave maximum per cent disease reduction over control after 4 sprays at ten days interval.

These findings are in confirmation with Benagi (1991), Nazeer *et al.* (1993), Gaikwad and Nimbalkar (2004), Alam *et al.* (2007) and Kalappanavar *et al.* (2008).

**5.6.2.2.2 Effect of fungicides on the yield parameters and monetary returns**

The fruit yield was found to increase in all the treatments when compared to the control. The highest BC ratio was observed in 0.1 per cent tebuconazole (3.94) followed by 0.1 per cent propiconazole (3.80) and 0.25 per cent mancozeb (3.47). The lower BC ratio in the treatments 0.1 per cent azoxystrobin and 0.2 per cent captan + hexaconazole compared to the control which is attributed to their high chemical cost.

As Singleton *et al.* (1982) has reported the disease severity reduces the yield which was reason for reduced yield in the control. The findinds on the monetary returns and BC ratio are in comparsion with the earlier workers Gaikwad and Nimbalkar (2004).

**Future line work**

Further, detailed studies need to be conducted in the following areas which will be helpful to develop the schedule for the effective management of the disease by utilizing the present outcomes and to study the molecular variability in different isolates of *C. fici*

- Screening of more fig genotypes for their resistance to rust disease
- Development of spray schedule based on disease prediction model
- Accurate method of spore load estimation has to be done with Burkhard spore trap to develop better forecasting model
- Pesticide residual analysis in fig fruits
- Molecular characterization of different isolates of *C. fici* by designing specific primers

# 6. SUMMARY AND CONCLUSIONS

Fig is an important deciduous fruit crop. The fruits are known for their nutritional importance, therefore the area under the cultivation of the crop is increasing day by day.

Among the different factors limiting its productivity, the rust disease caused by *Cerotelium fici* Cast. Arth. is major since, it causes more than 50 per cent yield loss. Therefore we have conducted research on management of fig rust in which we were committed to survey the major fig growing regions of North Karnataka, optimising of spore germination conditions, screening of fig varieties and *in vitro* and *in vivo* evaluation of fungicides, botanicals and bio-agents for the effective management of the disease.

Initially, symptoms of fig rust are visible as small, yellowish spots on upper surface of leaves. As these spots grow larger, they turn a reddish- brown colour. On the lower surface of the leaf, the lesions burst open to release the yellow to brown uredospores. Heavily infected leaves turn yellow or brown, particularly around the edges and drop prematurely. On petioles and shoots the brown elongated lesions are observed. Under severe infestation fruit quality is highly deteriorated. Uredospores of *C. fici* are elongated to oblong in shape, echinulated and have 1-3 germpores.

In the roving survey for fig rust severity during 2017-18, in the areas of Bagalkot, Ballary and Koppal districts of North Karnataka, it was observed that the disease was severe in all the fig growing regions and Ballary (66.93 PDI) district recorded maximum disease severity, whereas, minimum disease severity was recorded in Bagalkot district (51.46 PDI).

All the inoculation techniques *viz.*, dusting, leaf pinning, plaster and spray inoculation were found to be effective in production of maximum disease. The minmum latent period observed was seven days.

The maximum uredospore germination was recorded in 2.5 per cent sucrose and least in RO water (4.22%).The uredospore germination was maximum at 25˚ C (51.10%) and least germination was observed at 40˚ C (1.22%). The 100 per cent

relative humidity (58.92%) recorded maximum uredospore germination and there was no germination at 65 per cent relative humidity.

None of the fig variety was found resistant to the rust disease. The varieties Excel, Bellary, Dienna, Conadriya and Dinakar were highly susceptible to the disease, while Poona was found to be susceptible.

The correlation and regression analysis reveals that the relative humidity and temperature are most influencing factors on disease severity.

In the biochemical studies, it was evident that the pathogenesis increased the reducing sugars, total sugars, non reducing sugars, protein and phenol content in the lower leaves whereas chlorophyll content was reduced. The wax content of the lower leaves was less compared to the upper leaves in all the varieties.

The *in vitro* studies regarding the efficacy of fungicides aginst *C. fici* revealed that the systemic fungicides *viz.*, propiconaazole (98.67%), difenconazole (97.47%), carbendazim (97.39%) and tebuconazole (96.30%) were found as highly effective in inhibiting the uredospore germination at all the concentrations tested. Besides, these fungicides mancozeb (98.29%) and trifloxystrobin+tebuconazole (99.25%) were found highly effective at all the concentrations tested.

Among different biorationals tested neem oil (100.00%), safflower oil (100.00%), amrut pani (100.00%), coconut oil (98.80%), ginger rhizome extract (97.84%) and garlic bulb extract (90.29%) effectively inhibited the uredospore germination. The bacterial bio-agents *B. subtilis* and *P. fluoroscens* gave cent per cent inhibition of uredospore germination. The *L. lecanii* recorded the least uredospore inhibition.

The field evaluation of biorationals and bioagents revealed that ginger rhizome extract at 15 per cent, neem oil at 5 per cent, garlic bulb extract at 15 per cent were found highly effective in reducing the rust disease severity.

Among the different fungicides evaluated aginst *C. fici* under field condition tebuconazole at 0.1 per cent, propiconazole at 0.1 per cent and mancozeb at 0.25 per cent were found more effective by recording maximum disease reduction of 46.25, 40.84 and 39.99 per cent respectively over untreated control.

The yield was found to be increased due to the fungicidal treatment and highest BC ratio was observed in 0.1 per cent tebuconazole (1:3.99) followed by 0.1 per cent propiconazole (1:3.80) and 0.25 per cent mancozeb (1:3.47).

**Key findings of the present investigation**

- The fig rust caused by *C. fici* was highly severe in Ballary and Koppal districts
- Under *in vitro* 20-25˚ C temperature and 85 -100% RH is favourable for uredospore germination
- In the present study only Poona variety was susceptible to the disease while all other varieties were highly susceptible to the disease
- The morning relative humidity and minimum temperature have major influence on the disease severity
- *In vitro* efficacy of fungicides, biorationals and bioagents indicated that fungicides *viz.*, propiconazole, carbendazim, difenconazole, tebuconazole, mancozeb and trifloxystrobin+tebuconazole were found highly effective in inhibiting the uredospore germination at all the concentrations tested.
- Out of the different biorationals tested neem oil, safflower oil, amrut pani, ginger rhizome extract, coconut oil and garlic bulb extract effectively inhibited the uredospore germination.
- The bioagents *viz.*, *Bacillus. subtilis*, *Pseudomonas. fluoroscens* and *Lecanicillium lecanii* completely inhibited the uredospore germination.
- The biorationals garlic bulb extract (15%), ginger rhizome extract (15%), neem oil (5%) and bioagents *Bacilus subtilis* and *Lecanicillium lecanii* effectively reduced the disease severity
- The fungicides tebuconazole (0.1%), propiconazole (0.1%) and mazcozeb (0.25%) can be recommended for the management of the disease.

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**Appendix I: Meteorological data recorded at Main Horticultural Research and Extension Centre, UHS, Bagalkot**

**September, 2017**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-09-2017 | 92.80 | 38.30 | 33.20 | 23.70 | 0.00 |
| 02-09-2017 | 88.10 | 43.60 | 32.50 | 22.90 | 0.00 |
| 03-09-2017 | 84.30 | 43.20 | 33.10 | 23.90 | 0.00 |
| 04-09-2017 | 88.90 | 38.20 | 34.60 | 23.90 | 0.00 |
| 05-09-2017 | 85.40 | 59.50 | 30.60 | 24.60 | 0.00 |
| 06-09-2017 | 99.00 | 61.40 | 30.20 | 23.40 | 7.40 |
| 07-09-2017 | 99.50 | 53.20 | 32.10 | 23.90 | 36.70 |
| 08-09-2017 | 95.40 | 62.30 | 31.10 | 22.90 | 3.30 |
| 09-09-2017 | 91.40 | 47.30 | 33.40 | 25.00 | 0.00 |
| 10-09-2017 | 99.10 | 59.50 | 30.80 | 24.10 | 0.00 |
| 11-09-2017 | 87.70 | 52.90 | 32.80 | 25.60 | 0.00 |
| 12-09-2017 | 85.50 | 46.90 | 33.60 | 26.30 | 0.00 |
| 13-09-2017 | 86.90 | 50.50 | 34.20 | 24.50 | 57.20 |
| 14-09-2017 | 100.00 | 70.30 | 28.60 | 22.40 | 83.70 |
| 15-09-2017 | 99.20 | 71.60 | 29.00 | 23.30 | 3.50 |
| 16-09-2017 | 97.30 | 53.90 | 31.90 | 24.20 | 8.60 |
| 17-09-2017 | 95.60 | 72.40 | 27.30 | 22.90 | 3.00 |
| 18-09-2017 | 91.90 | 58.20 | 28.10 | 22.40 | 0.70 |
| 19-09-2017 | 86.50 | 61.20 | 27.60 | 23.40 | 0.00 |
| 20-09-2017 | 98.50 | 68.60 | 27.80 | 22.30 | 1.00 |
| 21-09-2017 | 89.00 | 63.90 | 27.60 | 22.70 | 0.00 |
| 22-09-2017 | 90.30 | 53.30 | 29.20 | 22.50 | 0.00 |
| 23-09-2017 | 94.60 | 47.40 | 32.10 | 22.10 | 0.50 |
| 24-09-2017 | 97.10 | 65.80 | 30.50 | 23.30 | 15.80 |
| 25-09-2017 | 100.00 | 76.90 | 27.80 | 22.30 | 8.30 |
| 26-09-2017 | 98.00 | 75.90 | 28.10 | 22.10 | 1.60 |
| 27-09-2017 | 99.10 | 56.30 | 31.50 | 22.60 | 22.30 |
| 28-09-2017 | 99.70 | 81.80 | 25.90 | 22.40 | 24.70 |
| 29-09-2017 | 100.00 | 75.90 | 27.60 | 22.00 | 8.00 |
| 30-09-2017 | 99.50 | 66.50 | 29.80 | 22.30 | 0.20 |

**October, 2107**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-10-2017 | 98.50 | 59.00 | 30.80 | 23.70 | 0.20 |
| 02-10-2017 | 94.00 | 60.90 | 31.10 | 23.20 | 0.00 |
| 03-10-2017 | 99.50 | 59.90 | 31.30 | 22.90 | 0.00 |
| 04-10-2017 | 99.50 | 59.10 | 31.10 | 24.20 | 0.00 |
| 05-10-2017 | 99.50 | 44.00 | 31.50 | 23.10 | 0.00 |
| 06-10-2017 | 91.10 | 62.10 | 29.80 | 23.80 | 9.00 |
| 07-10-2017 | 99.50 | 68.30 | 29.90 | 23.60 | 6.70 |
| 08-10-2017 | 100.00 | 58.50 | 31.80 | 23.60 | 0.00 |
| 09-10-2017 | 99.60 | 61.80 | 30.80 | 23.00 | 0.00 |
| 10-10-2017 | 95.60 | 62.00 | 30.50 | 23.90 | 0.00 |
| 11-10-2017 | 99.30 | 56.30 | 32.30 | 24.60 | 24.80 |
| 12-10-2017 | 100.00 | 52.90 | 32.80 | 23.10 | 5.50 |
| 13-10-2017 | 95.40 | 47.40 | 33.60 | 23.80 | 0.00 |
| 14-10-2017 | 99.10 | 58.40 | 32.30 | 23.30 | 3.40 |
| 15-10-2017 | 99.90 | 57.90 | 31.80 | 23.10 | 1.30 |
| 16-10-2017 | 99.90 | 58.70 | 32.50 | 23.30 | 1.30 |
| 17-10-2017 | 99.50 | 50.00 | 32.30 | 22.90 | 0.00 |
| 18-10-2017 | 99.50 | 19.00 | 33.70 | 22.30 | 0.00 |
| 19-10-2017 | 87.50 | 26.00 | 33.40 | 21.20 | 0.00 |
| 20-10-2017 | 90.70 | 33.90 | 31.90 | 20.20 | 0.00 |
| 21-10-2017 | 99.80 | 41.20 | 30.40 | 20.60 | 0.00 |
| 22-10-2017 | 90.10 | 55.00 | 30.40 | 22.90 | 0.20 |
| 23-10-2017 | 99.20 | 56.50 | 32.20 | 22.60 | 15.80 |
| 24-09-2017 | 100.00 | 54.10 | 30.20 | 22.90 | 0.00 |
| 25-10-2017 | 99.50 | 59.00 | 29.80 | 22.50 | 0.00 |
| 26-10-2017 | 92.80 | 47.60 | 31.60 | 23.70 | 0.00 |
| 27-10-2017 | 90.50 | 39.30 | 31.60 | 22.60 | 0.00 |
| 28-10-2017 | 92.30 | 34.70 | 31.90 | 20.60 | 0.00 |
| 29-10-2017 | 93.50 | 41.30 | 30.60 | 21.40 | 0.00 |
| 30-10-2017 | 93.70 | 29.20 | 31.50 | 20.80 | 0.00 |
| 31-10-2017 | 96.40 | 29.20 | 31.50 | 18.40 | 0.00 |

**November, 2017**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-11-2017 | 74.00 | 81.00 | 31.00 | 20.00 | 0.00 |
| 02-11-2017 | 70.00 | 82.00 | 30.40 | 19.40 | 0.00 |
| 03-11-2017 | 72.00 | 82.00 | 31.00 | 20.00 | 0.00 |
| 04-11-2017 | 70.00 | 78.00 | 30.60 | 19.00 | 0.00 |
| 05-11-2017 | 87.00 | 81.00 | 30.60 | 22.00 | 0.00 |
| 06-11-2017 | 78.00 | 81.00 | 29.00 | 22.00 | 0.00 |
| 07-11-2017 | 75.00 | 85.00 | 31.00 | 21.60 | 0.00 |
| 08-11-2017 | 85.00 | 73.00 | 31.00 | 21.60 | 0.00 |
| 09-11-2017 | 71.00 | 75.00 | 30.80 | 25.00 | 0.00 |
| 10-11-2017 | 67.00 | 89.00 | 31.00 | 20.40 | 0.00 |
| 11-11-2017 | 84.00 | 92.00 | 29.40 | 19.80 | 0.00 |
| 12-11-2017 | 62.00 | 98.00 | 29.00 | 20.40 | 0.00 |
| 13-11-2017 | 61.00 | 92.00 | 29.00 | 20.00 | 0.00 |
| 14-11-2017 | 44.00 | 87.00 | 31.00 | 19.00 | 0.00 |
| 15-11-2017 | 93.00 | 84.00 | 31.00 | 21.00 | 0.00 |
| 16-11-2017 | 95.00 | 77.00 | 31.00 | 20.80 | 0.00 |
| 17-11-2017 | 77.00 | 88.00 | 31.00 | 22.00 | 0.00 |
| 18-11-2017 | 76.00 | 85.00 | 30.80 | 22.40 | 0.00 |
| 19-11-2017 | 90.00 | 84.00 | 30.00 | 22.00 | 0.00 |
| 20-11-2017 | 77.00 | 84.00 | 30.80 | 24.00 | 0.00 |
| 21-11-2017 | 84.00 | 79.00 | 32.40 | 25.00 | 0.00 |
| 22-11-2017 | 74.00 | 83.00 | 32.40 | 23.80 | 0.00 |
| 23-11-2017 | 73.00 | 76.00 | 32.40 | 21.80 | 0.00 |
| 24-11-2017 | 78.00 | 52.00 | 31.80 | 21.80 | 0.00 |
| 25-11-2017 | 76.00 | 94.00 | 31.80 | 20.60 | 0.00 |
| 26-11-2017 | 76.00 | 88.00 | 30.00 | 21.00 | 0.00 |
| 27-11-2017 | 68.00 | 94.00 | 30.00 | 19.00 | 0.00 |
| 28-11-2017 | 67.00 | 81.00 | 30.40 | 19.00 | 0.00 |
| 29-11-2017 | 72.00 | 84.00 | 30.60 | 19.00 | 0.00 |
| 30-11-2017 | 80.00 | 94.00 | 30.80 | 18.80 | 0.00 |

**December, 2017**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-12-2017 | 83.00 | 84.00 | 29.00 | 20.00 | 0.00 |
| 02-12-2017 | 74.00 | 88.00 | 29.00 | 20.40 | 0.00 |
| 03-12-2017 | 66.00 | 85.00 | 27.60 | 19.40 | 0.00 |
| 04-12-2017 | 80.00 | 82.00 | 29.00 | 20.80 | 0.00 |
| 05-12-2017 | 85.00 | 81.00 | 30.60 | 26.00 | 0.00 |
| 06-12-2017 | 62.00 | 71.00 | 29.00 | 20.00 | 0.00 |
| 07-12-2017 | 76.00 | 68.00 | 31.00 | 20.40 | 0.00 |
| 08-12-2017 | 80.00 | 78.50 | 30.40 | 25.20 | 0.00 |
| 09-12-2017 | 60.00 | 73.00 | 30.60 | 20.60 | 0.00 |
| 10-12-2017 | 81.00 | 77.00 | 31.40 | 19.00 | 0.00 |
| 11-12-2017 | 75.00 | 78.00 | 31.80 | 20.00 | 0.00 |
| 12-12-2017 | 88.00 | 82.00 | 31.00 | 18.80 | 0.00 |
| 13-12-2017 | 88.00 | 77.00 | 31.40 | 18.00 | 0.00 |
| 14-12-2017 | 59.00 | 94.00 | 31.80 | 19.00 | 0.00 |
| 15-12-2017 | 75.00 | 85.00 | 30.80 | 21.60 | 0.00 |
| 16-12-2017 | 72.00 | 79.00 | 30.20 | 19.00 | 0.00 |
| 17-12-2017 | 74.00 | 72.00 | 30.00 | 18.00 | 0.00 |
| 18-12-2017 | 66.00 | 77.00 | 29.00 | 17.00 | 0.00 |
| 19-12-2017 | 65.00 | 94.00 | 28.00 | 17.00 | 0.00 |
| 20-12-2017 | 64.00 | 85.00 | 28.00 | 15.00 | 0.00 |
| 21-12-2017 | 64.00 | 79.00 | 28.80 | 15.00 | 0.00 |
| 22-12-2017 | 26.00 | 72.00 | 29.00 | 14.60 | 0.00 |
| 23-12-2017 | 64.00 | 78.00 | 29.00 | 15.60 | 0.00 |
| 24-12-2017 | 62.00 | 83.00 | 29.00 | 16.00 | 0.00 |
| 25-12-2017 | 51.00 | 61.00 | 29.40 | 14.00 | 0.00 |
| 26-12-2017 | 65.00 | 63.00 | 29.00 | 14.60 | 0.00 |
| 27-12-2017 | 65.00 | 74.00 | 30.40 | 15.00 | 0.00 |
| 28-12-2017 | 68.00 | 70.00 | 28.00 | 15.00 | 0.00 |
| 29-12-2017 | 72.00 | 92.00 | 27.80 | 15.60 | 0.00 |
| 30-12-2017 | 65.00 | 89.00 | 23.60 | 16.40 | 0.00 |
| 31-12-2017 | 50.00 | 76.00 | 28.00 | 17.00 | 0.00 |

**January, 2018**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-01-2018 | 63.00 | 35.80 | 28.60 | 14.00 | 0.00 |
| 02-01-2018 | 62.00 | 24.70 | 28.80 | 14.80 | 0.00 |
| 03-01-2018 | 56.00 | 25.20 | 30.40 | 19.00 | 0.00 |
| 04-01-2018 | 60.00 | 23.20 | 30.80 | 20.20 | 0.00 |
| 05-01-2018 | 74.00 | 28.60 | 29.00 | 19.50 | 0.00 |
| 06-01-2018 | 65.00 | 26.00 | 29.00 | 20.00 | 0.00 |
| 07-01-2018 | 65.00 | 28.00 | 29.00 | 21.60 | 0.00 |
| 08-01-2018 | 64.00 | 26.20 | 29.00 | 20.10 | 0.00 |
| 09-01-2018 | 42.00 | 19.00 | 28.80 | 17.80 | 0.00 |
| 10-01-2018 | 72.00 | 33.50 | 30.00 | 22.60 | 0.00 |
| 11-01-2018 | 71.00 | 19.00 | 31.60 | 22.20 | 0.00 |
| 12-01-2018 | 92.00 | 23.50 | 32.20 | 24.00 | 0.00 |
| 13-01-2018 | 69.00 | 35.80 | 32.40 | 24.20 | 0.00 |
| 14-01-2018 | 57.90 | 28.30 | 33.80 | 21.80 | 0.00 |
| 15-01-2018 | 57.40 | 24.70 | 33.40 | 21.30 | 0.00 |
| 16-01-2018 | 61.70 | 26.00 | 34.00 | 20.90 | 0.00 |
| 17-01-2018 | 65.20 | 25.20 | 32.40 | 20.60 | 0.00 |
| 18-01-2018 | 69.70 | 26.00 | 32.10 | 20.20 | 0.00 |
| 19-01-2018 | 703.00 | 26.90 | 30.70 | 18.90 | 0.00 |
| 20-01-2018 | 61.30 | 23.20 | 30.20 | 19.10 | 0.00 |
| 21-01-2018 | 50.90 | 19.00 | 31.30 | 19.40 | 0.00 |
| 22-01-2018 | 48.90 | 17.30 | 30.80 | 18.90 | 0.00 |
| 23-01-2018 | 49.10 | 19.00 | 30.90 | 18.50 | 0.00 |
| 24-01-2018 | 64.60 | 23.50 | 32.10 | 18.10 | 0.00 |
| 25-01-2018 | 64.60 | 28.60 | 30.30 | 17.60 | 0.00 |
| 26-01-2018 | 76.80 | 26.00 | 31.10 | 17.60 | 0.00 |
| 27-01-2018 | 40.30 | 19.00 | 31.30 | 19.30 | 0.00 |
| 28-01-2018 | 66.40 | 19.00 | 32.20 | 16.90 | 0.00 |
| 29-01-2018 | 58.40 | 19.00 | 32.20 | 19.20 | 0.00 |
| 30-01-2018 | 64.90 | 26.00 | 31.60 | 20.80 | 0.00 |
| 31-01-2018 | 58.30 | 19.00 | 30.60 | 19.40 | 0.00 |

**February, 2018**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-02-2018 | 79.70 | 12.00 | 31.40 | 11.80 | 0.00 |
| 02-02-2018 | 60.40 | 12.00 | 31.80 | 12.90 | 0.00 |
| 03-02-2018 | 56.30 | 9.40 | 33.10 | 12.40 | 0.00 |
| 04-02-2018 | 44.30 | 10.30 | 32.80 | 15.20 | 0.00 |
| 05-02-2018 | 54.00 | 11.20 | 32.30 | 13.80 | 0.00 |
| 06-02-2018 | 51.20 | 10.30 | 31.90 | 15.20 | 0.00 |
| 07-02-2018 | 44.80 | 28.10 | 26.30 | 18.70 | 0.00 |
| 08-02-2018 | 84.70 | 19.00 | 24.30 | 15.20 | 0.00 |
| 09-02-2018 | 72.50 | 19.00 | 31.70 | 18.90 | 0.00 |
| 10-02-2018 | 61.10 | 26.20 | 30.40 | 18.00 | 0.00 |
| 11-02-2018 | 69.20 | 33.50 | 33.60 | 19.40 | 0.00 |
| 12-02-2018 | 80.40 | 28.90 | 32.70 | 19.30 | 0.00 |
| 13-02-2018 | 70.70 | 37.80 | 31.60 | 19.60 | 0.00 |
| 14-02-2018 | 69.60 | 33.00 | 32.20 | 19.80 | 0.00 |
| 15-02-2018 | 73.50 | 19.00 | 33.20 | 19.20 | 0.00 |
| 16-02-2018 | 53.00 | 19.00 | 32.80 | 19.10 | 0.00 |
| 17/0/2018 | 77.90 | 19.00 | 33.50 | 16.60 | 0.00 |
| 18-02-2018 | 59.00 | 11.20 | 35.20 | 15.90 | 0.00 |
| 19-02-2018 | 50.80 | 16.40 | 35.10 | 17.30 | 0.00 |
| 20-02-2018 | 50.20 | 19.00 | 34.70 | 20.80 | 0.00 |
| 21-02-2018 | 61.80 | 19.00 | 34.90 | 17.90 | 0.00 |
| 22-02-2018 | 51.60 | 19.00 | 35.30 | 18.60 | 0.00 |
| 23-02-2018 | 52.30 | 19.00 | 34.90 | 18.90 | 0.00 |
| 24-02-2018 | 51.40 | 12.00 | 34.60 | 19.10 | 0.00 |
| 25-02-2018 | 53.20 | 7.70 | 34.30 | 16.00 | 0.00 |
| 26-02-2018 | 42.10 | 8.50 | 35.60 | 14.30 | 0.00 |
| 27-02-2018 | 34.50 | 8.50 | 35.90 | 16.10 | 0.00 |
| 28-02-2018 | 37.30 | 9.40 | 35.80 | 17.80 | 0.00 |

**March, 2018**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-03-2018 | 30.00 | 10.30 | 36.40 | 23.10 | 0.00 |
| 02-03-2018 | 26.40 | 11.20 | 36.40 | 24.00 | 0.00 |
| 03-03-2018 | 28.30 | 9.40 | 37.10 | 24.20 | 0.00 |
| 04-03-2018 | 63.90 | 13.80 | 37.30 | 24.30 | 0.00 |
| 05-03-2018 | 75.50 | 9.40 | 37.80 | 23.40 | 0.00 |
| 06-03-2018 | 53.30 | 9.40 | 37.40 | 24.20 | 0.00 |
| 07-03-2018 | 25.50 | 8.50 | 38.20 | 24.70 | 0.00 |
| 08-03-2018 | 57.50 | 8.50 | 38.10 | 23.30 | 0.00 |
| 09-03-2018 | 53.90 | 19.00 | 36.90 | 23.40 | 0.00 |
| 10-03-2018 | 27.70 | 10.30 | 38.30 | 25.70 | 0.00 |
| 11-03-2018 | 42.20 | 18.20 | 37.70 | 25.40 | 0.00 |
| 12-03-2018 | 34.40 | 11.20 | 37.20 | 27.30 | 0.00 |
| 13-03-2018 | 44.20 | 13.80 | 37.80 | 27.00 | 0.00 |
| 14-03-2018 | 38.80 | 12.90 | 37.50 | 27.30 | 0.00 |
| 15-03-2018 | 68.80 | 27.50 | 33.30 | 26.60 | 0.00 |
| 16-03-2018 | 74.50 | 28.70 | 32.80 | 23.50 | 0.00 |
| 17-03-2018 | 59.00 | 38.50 | 31.80 | 24.70 | 0.00 |
| 18-03-2018 | 74.70 | 33.50 | 35.60 | 25.80 | 0.00 |
| 19-03-2018 | 60.10 | 26.00 | 38.20 | 27.30 | 0.00 |
| 20-03-2018 | 60.10 | 19.00 | 37.60 | 26.20 | 0.00 |
| 21-03-2018 | 35.90 | 19.00 | 38.00 | 26.30 | 0.00 |
| 22-03-2018 | 52.60 | 17.30 | 36.40 | 24.30 | 0.00 |
| 23-03-2018 | 34.60 | 13.80 | 37.90 | 24.40 | 0.00 |
| 24-03-2018 | 32.40 | 10.30 | 38.80 | 26.70 | 0.00 |
| 25-03-2018 | 30.10 | 19.00 | 38.40 | 27.60 | 0.00 |
| 26-03-2018 | 38.60 | 19.00 | 38.20 | 28.90 | 0.00 |
| 27-03-2018 | 60.60 | 19.00 | 40.10 | 27.90 | 0.00 |
| 28-03-2018 | 66.20 | 14.70 | 40.10 | 28.40 | 0.00 |
| 29-03-2018 | 70.80 | 19.00 | 39.10 | 26.20 | 0.00 |
| 30-03-2018 | 63.20 | 12.00 | 39.10 | 26.60 | 0.00 |
| 31-03-2018 | 68.90 | 9.40 | 39.70 | 25.30 | 0.00 |

**April, 2018**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-04-2018 | 53.20 | 10.30 | 40.30 | 26.00 | 0.00 |
| 02-04-2018 | 50.00 | 12.90 | 39.40 | 27.50 | 0.00 |
| 03-04-2018 | 28.80 | 14.70 | 39.60 | 27.60 | 0.00 |
| 04-04-2018 | 59.60 | 19.00 | 39.40 | 28.90 | 0.00 |
| 05-04-2018 | 58.30 | 19.00 | 38.30 | 28.90 | 0.00 |
| 06-04-2018 | 64.30 | 27.30 | 38.70 | 27.60 | 0.00 |
| 07-04-2018 | 62.20 | 19.00 | 38.80 | 24.80 | 1.40 |
| 08-04-2018 | 42.80 | 19.00 | 36.20 | 27.10 | 0.00 |
| 09-04-2018 | 42.00 | 19.00 | 36.10 | 29.00 | 0.00 |
| 10-04-2018 | 44.90 | 19.00 | 37.60 | 28.20 | 0.00 |
| 11-04-2018 | 44.30 | 19.50 | 38.10 | 28.30 | 0.00 |
| 12-04-2018 | 42.50 | 19.00 | 38.20 | 29.40 | 0.00 |
| 13-04-2018 | 41.30 | 19.00 | 40.20 | 30.80 | 4.50 |
| 14-04-2018 | 61.90 | 19.00 | 38.70 | 28.60 | 0.00 |
| 15-04-2018 | 67.80 | 27.60 | 38.10 | 27.90 | 14.00 |
| 16-04-2018 | 71.50 | 28.30 | 36.40 | 27.10 | 0.20 |
| 17-04-2018 | 64.60 | 26.20 | 39.10 | 29.80 | 1.70 |
| 18-04-2018 | 59.80 | 27.60 | 37.90 | 27.30 | 0.00 |
| 19-04-2018 | 59.90 | 14.70 | 40.20 | 30.70 | 0.00 |
| 20-04-2018 | 71.20 | 19.00 | 38.60 | 28.10 | 0.00 |
| 21-04-2018 | 80.00 | 12.90 | 40.20 | 23.30 | 0.00 |
| 22-04-2018 | 35.30 | 12.90 | 41.60 | 31.30 | 0.00 |
| 23-04-2018 | 54.70 | 19.00 | 39.60 | 28.60 | 0.00 |
| 24-04-2018 | 48.30 | 9.40 | 41.30 | 29.30 | 0.00 |
| 25-04-2018 | 54.60 | 9.40 | 40.60 | 29.10 | 0.00 |
| 26-04-2018 | 47.20 | 8.50 | 40.00 | 28.40 | 0.00 |
| 27-04-2018 | 52.10 | 19.00 | 40.50 | 28.30 | 0.00 |
| 28-04-2018 | 46.90 | 19.00 | 41.10 | 29.50 | 3.00 |
| 29-04-2018 | 68.80 | 19.00 | 40.90 | 27.80 | 0.00 |
| 30-04-2018 | 62.90 | 19.00 | 39.60 | 28.10 | 0.00 |

**May, 2108**

| Date | RH morning | RH afternoon | Max temp | Min temp | Rainfall |
|---|---|---|---|---|---|
| 01-05-2018 | 57.20 | 19.00 | 40.80 | 27.90 | 0.00 |
| 02-05-2018 | 58.30 | 19.00 | 39.90 | 27.90 | 0.00 |
| 03-05-2018 | 70.60 | 19.00 | 39.70 | 26.80 | 0.00 |
| 04-05-2018 | 58.10 | 27.60 | 38.30 | 28.80 | 0.00 |
| 05-05-2018 | 61.70 | 23.00 | 39.90 | 30.10 | 0.00 |
| 06-05-2018 | 64.90 | 26.00 | 41.10 | 30.10 | 0.00 |
| 07-05-2018 | 57.60 | 30.10 | 38.80 | 28.20 | 0.00 |
| 08-05-2018 | 55.70 | 19.00 | 39.80 | 29.40 | 0.00 |
| 09-05-2018 | 64.30 | 19.00 | 40.20 | 28.10 | 22.30 |
| 10-05-2018 | 66.50 | 36.10 | 36.00 | 28.20 | 0.40 |
| 11-05-2018 | 62.20 | 27.20 | 39.40 | 26.70 | 15.00 |
| 12-05-2018 | 73.70 | 43.80 | 34.10 | 26.90 | 0.00 |
| 13-05-2018 | 69.40 | 32.30 | 37.80 | 27.30 | 0.00 |
| 14-05-2018 | 66.20 | 34.10 | 36.90 | 26.80 | 0.00 |
| 15-05-2018 | 67.30 | 31.30 | 36.30 | 26.10 | 0.00 |
| 16-05-2018 | 47.50 | 19.00 | 38.80 | 29.40 | 0.00 |
| 17-05-2018 | 57.30 | 27.50 | 37.50 | 29.00 | 0.00 |
| 18-05-2018 | 77.40 | 37.60 | 35.20 | 25.00 | 0.40 |
| 19-05-2018 | 71.20 | 28.30 | 38.20 | 28.50 | 0.00 |
| 20-05-2018 | 73.50 | 33.20 | 36.30 | 26.40 | 0.00 |
| 21-05-2018 | 66.60 | 26.20 | 39.00 | 27.90 | 1.00 |
| 22-05-2018 | 67.20 | 28.60 | 37.20 | 27.90 | 0.00 |
| 23-05-2018 | 66.90 | 27.60 | 39.60 | 29.10 | 1.20 |
| 24-05-2018 | 76.20 | 42.30 | 35.10 | 26.40 | 0.20 |
| 25-05-2018 | 69.00 | 36.00 | 35.70 | 27.60 | 0.00 |
| 26-05-2018 | 66.30 | 30.10 | 38.00 | 27.80 | 0.00 |
| 27-05-2018 | 72.20 | 42.30 | 34.60 | 25.60 | 0.00 |
| 28-05-2018 | 81.50 | 33.00 | 38.70 | 28.20 | 0.00 |
| 29-05-2018 | 71.90 | 33.50 | 38.40 | 28.70 | 5.00 |
| 30-05-2018 | 75.00 | 38.50 | 36.20 | 27.40 | 0.00 |
| 31-05-2018 | 72.50 | 33.20 | 38.70 | 27.90 | 0.00 |

**Appendix II: Cost of cultivation of fig during 2017-18**

**(Lokappa *et al*., 2018)**

| Sl. No. | Material/ Works | Cost perunit /Rate (Rs.) | 3rd Year crop Per hectare (Rs.) |
|---|---|---|---|
| **I** | **Inputs** | | |
| 1. | FYM @ 5 ton/ha | 1500 | 7500.00 |
| 2. | Fertilizers (100:66:66 Kg NPK/ha) | | |
| | a. Urea : 217.40 Kg | 5.90 | 1282.66 |
| | b. SSP : 412.50 Kg | 7.34 | 3027.75 |
| | c. MOP : 110.00 Kg | 14.00 | 1540.00 |
| **II** | **Labour charges** | | |
| 1. | Weeding | 250.00 | 2500.00 |
| 2. | Prunning | 250.00 | 5000.00 |
| 3. | FYM & Fertilizer application | 250.00 | 1500.00 |
| 4. | Spraying | 250.00 | 1500.00 |
| 5. | Harvesting | 250.00 | 5000.00 |
| **III** | **Other expenses** | | |
| 1. | Misc. expenses- Amortized Establishment Cost @ Rs. 8240 / acre | 20600.00 | 20600.00 |
| | | **Total (Rs.)** | **49450.41** |

**Appendix III: Cost of fungicides used in the experiment during 2017-18**

| Sl. No. | Name of the fungicide | Trade name | Quantity (g or ml) | Cost (Rs.) |
|---|---|---|---|---|
| 1. | Azoxystrobin 23% SC | Amistar | 200 | 1240.00 |
| 2. | Captan 70% + Hexaconazole 5% WP | Taqat | 100 | 162.00 |
| 3. | Carbendazim 50% WP | Bavistin | 500 | 630.00 |
| 4. | Difenconazole 25.0% EC | Score 250 SC | 50 | 245.00 |
| 5. | Hexaconazole 5% EC | Contaf | 500 | 339.00 |
| 6. | Kreoxim methyl 44.3% w/w | Ergon | 250 | 323.00 |
| 7. | Mancozeb 75% | Indofil M-45 | 250 | 120.00 |
| 8. | Propiconazole 25.0% EC | Tilt | 425 | 250.00 |
| 9. | Tebuconazole 25.9% EC | Folicur | 100 | 253.00 |

**EPIDEMIOLOGY AND MANAGEMENT OF FIG RUST CAUSED BY *Cerotelium fici* (Cast.) Arth.**

**ANUSHA A.** **2018** **Dr. MAHESH Y. S.**
**MAJOR ADVISOR**

## ABSTRACT

The present research work on "Epidemiology and management of fig rust caused by *Cerotelium fici* (Cast.) Arth." was carried out at Department of Plant Pathology, College of Horticulture, Bagalkot and *in vivo* studies at Fruit orchard, UHS, Bagalkot and Horticulture Research and Extension Centre, Vijayapura (Tidagundi) during 2017-2018.

The symptoms of fig rust was more pronounced on the leaves as brownish angular spots on the adaxial surface and uredosori on the corresponding abaxial surface of the leaf. The severity of the disease leads to the defoliation. The survey carried out in the three districts of Northern Karnataka revealed that the highest Percent Disease Index (PDI) was recorded in Ballary (66.93) and lowest in Bagalkot district (51.46). The *in vitro* studies on uredospore germination revealed that, 2.5 per cent sucrose, 25˚ C temperature and 100 per cent relative humidity favoured the maximum germination of uredospores.

Among the weather parameters correlated, morning relative humidity (%) and minimum temperature (˚C) had maximum influence on the disease development. *In vivo* screening of varieties *viz.,* Ballary, Conadriya, Dienna, Dinakar, Excel and Poona showed that none of the varieties were found to be resistant to rust disease. The results of analysis of bio chemical parameters showed that total sugars, reducing sugars, non reducing sugars, total protein and total phenol content in the leaves were increased due to the infection, whereas the chlorophyll content was decreased. The wax content, a pre existing defense component was highest in the upper leaves which were immune to the disease.

*In vitro* efficacy of fungicides, biorationals and bioagents indicated that fungicides *viz.,* propiconazole, carbendazim, difenconazole, tebuconazole, mancozeb and trifloxystrobin+tebuconazole were found highly effective in inhibiting the uredospore germination. Out of the different biorationals tested neem oil, safflower oil, amrut pani, ginger rhizome extract, coconut oil and garlic bulb extract effectively inhibited the uredospore germination. Among the bioagents *viz.*, *Bacillus. subtilis*, *Pseudomonas. fluoroscens* and *Lecanicillium lecanii*, completely inhibited the uredospore germination.

*In vivo* (field) evaluation studies indicated that among biorationals, ginger rhizome extract @ 15% was more effective in reducing the rust disease followed by neem oil @ 5% and garlic bulb extract @ 15%. Among the different fungicides tested, tebuconazole at 0.1 % propiconazole at 0.1 % and mancozeb at 0.25 % were recorded the least PDI of 31.85, 35.06, 35.56 and highest BC ratio of 1:3.94, 1:3.80, 1:3.47 respectively.

**¸gÉÉÃnÃ°AiÀÄ ¦ü (PÁ¸ï) Cxïð. ¢AzÀGAmÁUÀªÀCAdÆgÀvÀPÀgÉÃUÀÀ ¸ÉÃAPÀÆÁ¸ÀªÀvÀ¤ªÀ°ÀÉ**

**C£ÀµÀJ. 2018 qÁ. ªÀÄºÉÆÃï ªÉJ¸ï. ¥ÀæªÀÄ£À¸À°ÉÁgÀÀ**

**¸ÁgÁA±À**

¥ÀæAv ¸A±ÆÃz£AiiÁz "¸gÆÃnÃ°AiÄA ¦¹ (PÁ¸ï) Cxïð ¢Az GAmÁUÄª CAdÆg vÄPÄ gÆÃUz ¸ÆÃAPÄ±Á¸¦ ªÄvÄ ¤ªðºu" AiÄ£Ä¸¸¦ gÆÃU±Á¸¦ «¨ÁU, vÆÃlUÁjP ªÄºÁ«zÁ®AiÄ, ¨ÁU®PÆÃl ªÄvÄ PÃvæ¥ÀæÆÃUª£Ä ºtÄ «¨ÁU, vÆÃlUÁjP «eÁ£U¼ «±«zÁ®AiÄ, ¨ÁU®PÆÃl ªÄvÄ vÆÃlUÁjP ¸A±ÆÃz£Á ªÄvÄ «¸guÁ PÃAzæ «dAiÄ¥Ägz° (wqUÄA¢) 2017-18 £Ã ¸Á°£° PÉUÆ¼¯ÁVz.

PAzÄ §tz PÆÃ¤ÃAiÄ ZÄPÉU¼Ä J¯AiÄ ªÄÃ¯ÁUz° ªÄvÄ gÆÃUÁtÄ«£ AiÄÄjqÆÃ©ÃdPÆÃ± UÆAZ®ÄU¼Ä P¼¨ÁUz° CwAiiÁV PAqÄ§gÄvª ªÄvÄ gÆÃUz wÃªæAiÄÄ J¯ GzÄgÄ«PU PÁgtªÁUÄvz. Gvg P£ÁðlPz ¨ÁU®PÆÃl, §¼Áj ªÄvÄ PÆ¥¼ f¯U¼° PÉUÆAq gÆÃU ¸«ÄÄPÃAiÄ ¥Æég §¼Áj (66.93) f¯Aiİ° CvÉ¢P ªÄvÄ ¨ÁU®PÆÃl (51.46) f¯Aiİ° P¤µ gÆÃU ¸ÆZÉAP PAqÄ§A¢z. ±ÃPqÁ 2.5 gµÄ ¸ÄPÆÃçï, 25 rVæ. vÁ¥ªiÁ£ ºÁUÆ ±ÃPqÁ 100 ¸Á¥ÃP Dzæav EªÉ AiÄÄjqÆÃ©ÃdPtU¼ CAPÄgt ¥ÀæiÁtª£Ä ºa¹gÄªÉzÄ PAqÄ §A¢z.

ºªÁªiÁ£ ¤AiÄvÁAPU¼° ¨¼V£ ¸Á¥ÃP Dzæav ªÄvÄ P¤µ vÁ¥ªiÁ£U¼Ä gÆÃUz ¨¼ªtUAiÄ ªÄÃ¯ Ujµ ¥ÆéÁª ©Ãjz. ¥jÃQ¹z J¯Á v½U¼Æ (§¼Áj, PÆÃ£ÁrÀæÄ, rAiÄ£Ä, ¢£Pg, JP¯ï ªÄvÄ ¥Æ£Á) PÆq gÆÃU¤gÆÃzP ±QAiÄ£Ä ºÆA¢®ªAzÄ CzÉAiÄ£¢Az zÉq¥nz. gÆÃU¨Á¢v J¯U¼° eÉ«P ºÁUÆ gÁ¸ÁAiÄ¤P ¤AiÄvÁAPU¼Áz MlÄ ¸Pg, C¥PµðP ¸Pg, C¥PµðPª®z ¸Pg, MlÄ ¸¸Ágd£P ªÄvÄ MlÄ ¦£Á¯ïU¼ ¥ÀæiÁt ºaz. Dzg ¥vÀæjw£ ¥ÀæiÁt PrªÄAiiÁVgÄªÉzÄ PAqÄ§A¢gÄvz. ªÄÃtz ¥ÀæiÁtªÉ Vqz J¼AiÄ J¯U¼° ºZÁVzÄ gÆÃU¤gÆÃzP ±QU PÁgtªÁVz.

¥ÀæÆÃUÁ®AiÄz CzÉAiÄ£z ¥Æég ¥jÃQ¹z ««z ²°ÃAzÀæÁ±PU¼° ¥ÆqÆPÆ£ÁeÆ¯ï, PÁ¨ðAqfªiï, qÉ¥£ïPÆ£ÁeÆ¯ï, m§ÄPÆ£ÁeÆ¯ï, ªiÁAPÆÃe¨ï ªÄvÄ mÁæ¥ÆÃQ¸ÆÃ©£ï + m§ÄPÆ£ÁeÆ¯ï AiÄÄjqÆÃ©ÃdPt CAPÄgtz ¥ÀæiÁtª£Ä vqAiÄÄª° ºZÄ ¥juÁªÄPÁjAiÄAzÄ PAqÄ§A¢z. ««z eÉ«P «ªÃZÁ£ÁvPU¼° ¨Ã«£ Ju, PÄ¸Ä© Ju, CªÄv ¥Á¤, ±ÄAp PµÁAiÄ, PÆ§j Ju ªÄvÄ ¨¼Á½ PµÁAiÄ ¥juÁªÄPÁjAiiÁV AiÄÄjqÆÃ©ÃdPt CAPÄgtª£Ä ¤AiÄAwæz. ¨Á¹®¸ï ¸©°¸ï, ¸ÆqÆÃªÆ£Á¸ï ¥ÆgÆ¸£ï ªÄvÄ ¯PÁ¤¹°AiÄA ¯PÁ¤ fÃªÁtÄU¼Ä ¸A¥ÆtðªÁV AiÄÄjqÆÃ©ÃdPtz CAPÄgtª£Ä ¤©ðA¢¹ª.

PÃvæCzÉAiÄ£z° ±ÃPqÁ 15g ±ÄAp PµÁAiÄªÉ ºZÄ ¥juÁªÄPÁjAiiÁV vÄPÄ gÆÃUª£Ä ¤AiÄAwæÀªÉzAzÄ PAqÄ§A¢gÄvz ºÁUÆ vz£Avg ±ÃPqÁ 5g ¨Ã«£ Ju ªÄvÄ ±ÃPqÁ 15g ¨¼Á½ PµÁAiÄ ¥juÁªÄPÁjAiÄAzÄ PAqÄ§A¢z. ¥jÃQ¹z ²°ÃAzÀæÁ±PU¼°, m§ÄPÆ£ÁeÆ¯ï (0.1%), ¥ÆqÆPÆ£ÁeÆ¯ï (0.1%) ªÄvÄ ªiÁAPÆÃe¨ï (0.25%) PÀæªÁV 31.85, 35.06 ªÄvÄ 35.56 CwÃ PrªÄ gÆÃU¸ÆZÁAPU¼£Ä ºÁUÆ CvÉ¢P ¯Á¨-ªZ C£Ä¥ÁvU¼£Ä CAzg 1:3.94, 1:3.80 ªÄvÄ 1:3.47 C£Ä vÆÃj¹ª.