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

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BY

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CERTIFICATE

This is to certify that the thesis entitled "**EPIDEMIOLOGY AND MANAGEMENT OF FIG RUST (*Cerotelium fici* (Cast.) Arth.)**" *submitted by* **Mr. SREEKANTAPPA H.** *for the degree of* **MASTER OF SCIENCE (AGRICULTURE)** in **PLANT PATHOLOGY** *of the College of Agriculture, Raichur, University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his 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.*

RAICHUR
AUGUST, 2000

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INTRODUCTION

I. INTRODUCTION

Fig (*Ficus carica* L.) is an important deciduous fruit crop in tropical and subtropical countries and also highly delicious fruit known for its medicinal value. Being a potentially high value fruit crop for dry land horticulture, it is used in fresh and dried form. Of the total world production, Spain produces around 30% and other leading producers are Italy (20%), Turkey (15%) and Greece (10%) which account for 6.4 to 10 million hectares with 0.35 million tonnes of production on dry basis. It is commonly called as fig in English, Anjeer in Hindi and Anjura in Kannada. In India, area under fig is increasing every year. Among the various states of India, Pune district of Maharashtra is the largest followed by Karnataka, Uttar Pradesh, Punjab, Bihar and West Bengal. In Karnataka the crop is grown in an area of 350 hectares with a production of 3500 tonnes (Anonymous 1998).

Fig fruits are consumed fresh or dried, preserved, candied or canned. Being wholesome and nutritious, it is used as dessert or for making jam. The great bulk of fruit is consumed as dried fruit. Fruits are valued for their laxative properties and have great medicinal uses. When dried and ground it can be used as a substitute for coffee.

Fresh figs generally consist of 84 per cent pulp and 16 per cent skin, Nutritionally, the fig is composed of protein 1 - 3 g, fat

0.2g, minerals 0.6g, fibre 2.2g, carbohydrates 7.6g, energy (kcal) 37, calcium 80 mg, phosphorus 30 mg, Iron 1.0 mg, carotene 162 mg, thiamine 0.6 mg, high total sugar and vitamin C 5mg per 100 g, of edible proportion (Gopalan *et al.*, 1980 ; Bose and Mitra, 1990). Various medicinal properties and its application for boils and other skin infection are reported by Polumin and Huxley (1965) and Font Quer (1973). The latex from fig contains rennin (ficin), which has 30 to 100 times milk clotting activity as compared to animal rennet prepared from calf stomach mucosa. It is also used as an antihelminthic agent. (Srivastava and Vatsya,1986).

The fig is one of the most salt and drought tolerant crops (Samson, 1980). It can tolerate a fairly high level of sulphate or chloride salt, soils having a high lime content and can produce fruits of better quality suitable for drying. Fig is subjected to a number of destructive diseases at different stages of its growth and development including transit and storage. The wide range of climatic condition and environmental situations in which fig grows indicate the nature and the diversity of the associated disease problems.

There are a number of diseases affecting various parts of fig plant such as bacterial canker, crown gall, fruit rot, stem canker, leaf spot leaf blotch and fig rust etc. (Ferguson *et al.*, 1990). Rust caused by *Cerotelium fici* (Cast) Arth. is one of the common diseases of fig and

causes severe damage leading to defoliation of leaves and reduction in yield. (Pathak, 1980). In India the disease was first reported by Butler (1914).

Although, the disease is considered to be the most important one occurring in the north-eastern dry zone of Karnataka, so far no work has been initiated on disease problem of this dry zone fruit crop. Hence, a study involving survey of the disease over a period of time was considered to know the intensity with which it affects the yield and quality in addition to environmental impact of disease in different conditions. Hence, the survey was conducted to know the severity and distribution of rust of fig in Raichur, Bellary and Koppal districts.

The study on rust development in relation to environmental factors would help us to quantify the correlation and the variability existing among the different independent variables on the dependent variable.

Biochemical studies in healthy and diseased plants would unravel the post-infectional biochemical changes and the resistance offered there to.

Evaluation of fungitoxicants including new generation molecules were under taken in laboratory and field conditions to know their relative efficacy in controlling the rust disease subsequently to recommended them in managing the disease.

The present studies were therefore, directed to throw some light on several of these aspects by conceiving the following well defined objectives .

1. To under take survey of rust in fig growing areas of Raichur, Koppal and Bellary districts.

2. To study the disease development in relation to environmental factors and to explore the possibility of development of prediction model.

3. To know the biochemical aspects with respect to healthy v/s diseased leaves.

4. To evaluate fungicides and new generation molecules against fig rust under *in vitro* and *in vivo* conditions.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Fig is gaining importance as a major fruit crop under dry land horticulture and rust caused by *Cerotelium fici* (Cast.) Arth. is a number one destructive disease affecting the crop among the diseases reported in India. However, the literature available on this disease is very scanty. Hence, the present chapter reviews whatever little information available actually on fig rust along with the information on rust of related crops.

2.1 Historical

The genus *Cerotelium* was established by Arther (1906). The fig rust caused by *C. fici* was first reported by Butler (1914) in India. Since then it has been reported and described from several parts of India such as Nagaland, Arunachal Pradesh and Punjab (Ahmed 1981; Verma and Kapur, 1995). Later, *Aecidium mori* and *Cerotelium fici* (Cast.) Arth. have been reported to be the cause of rust in *Morus alba* L. and *M. alba* L. (Sydow and Butler, 1907 and Patel and Kamat, 1949). Rust also occurs on many wild species of *Ficus*. Arthur (1934) placed the rust under *Physopella* and named it as *Physopella fici* (Cast.). Arth. There after, *Physopella* has been merged partly with *Phakopsora* and partly with *Cerotelium*.

2.2 Symptomatology

Rust of fig is characterized by small, round, reddish brown spot, black, eruptive lesions on leaves, with raised rusty brown

pustules appearing on lower surface of leaves, covering almost entire leaf blade. The affected leaves dried and dropped down, coupled with immature dropping of fruits (Dhamo, 1975). During heavy rains, the entire leaf became reddish brown which got defoliated from the tree and fruits also dropped off thus reduced the yield. Teliosori were less powdery in appearance than uredosori (Thirumalachar *et al.*, 1950). The rust caused severe defoliation and reduction in yield (Pathak, 1980). Similar nature of symptoms was also observed by Chalfoun *et al.* (1997).

2.3 Morphology of the pathogen

The morphology of the pathogen was described as uredinium which was found to be subepidermal in origin, peridiate with cellular peridium, uredinospores sessile, singly arranged on the basal cells. The telium was in compact subepidermal lanceolate crusts with delicate peridium and macrocyclic in nature (Arthur, 1906; Arun, 1972).

In *Cerotelium*, the spermogonia were subculticular and flattened. Aecia were subepidermal, erumpent, with peridium which were slightly recurved. The aeciospores were catenulate or verrucase. Uredinia were subepidermal, only slightly erumpent, with peripheral basally united and paraphyses present or absent. Uredinospores were echinulate and borne singly on simple and short pedicels. Telia were mostly hypophyllous, cinnamon yellow, waxy, subepidermal and erumpent. Teliospores were

hyaline, one-celled but united in chains of two to several spores. These chains formed a pallisade layer in the sorus. Mature spores were oblong – ellipsoid to ovate measuring 14- 21 x11 – 13µ. Teliospore from telia, germinated with out any dormancy (Butler, 1914). *Cerotelium* is macro cyclic in nature as reported by Cummins (1959). Ono (1995) rediscovered *C. asari* on *Asarum caulescens* in Ibaraki, Japan and its life cycle was found to be heterocious in nature.

2.4 Host range

Ficus carica L., was reported to be a host for *C.fici* (Arthur, 1906). *Morus indica L., Morus alba* L. and *Ficus religiosa* were among the other host plants of *Cerotelium fici* (Patel and Kamat, 1949; Sinha and Singh, 1992). *Ficus rumphi* was reported to be an additional host for *C. fici* (Butl.) Arth. (Khan, 1994). *Grewia asiatica* and fig were hosts of *C.fici* as noticed by Verma and Kapur (1995).

2.5 Survey and surveillance of fig rust

Rust is widely distributed in the tropical and sub tropical regions where figs are cultivated (Thirumalachar, *et al.*, 1950; Cheema *et al.*, 1954). Many fig orchards in India have become unproductive due to damage caused by rust disease. Padule *et al.* (1988) observed that fig is cultivated in pockets of Pune district of Maharashtra, Rajasthan and Karnataka where in fig rust was the only problem causing considerable

damage. Of late, the disease has become epiphytotic, resulting in huge yield losses.

A survey reported in mulberry indicated a number of diseases, of which leaf rust was the most serious and caused a direct loss of leaves due to premature defoliation and destruction of leaf area (Sastry 1984; Sukumar and Ramalingam, 1989). *C.fici* on *Ficus religiosa* was recently reported in Patna, India (Sinha and Singh, 1992). A systematic survey was undertaken during 1990-1992 in selected mulberry growing areas under different agroclimatic zones located in Andhra Pradesh, Karnataka, Kerala and Tamil Nadu. High incidence of leaf rust was observed during winter followed by rainy season. High incidence was noticed in Karnataka during winter (Gunasekhar *et al.*, 1994).

Verma and Kapur (1995) recorded the occurrence of some new diseases of fruits from Punjab recently during orchard surveys in Ludhiana, which included leaf and shoot blight caused by *Pestalotiopsis psidii*, on guava, rust *(C.fici)* of *Grewia asiatic* and fig. Philip *et al.* (1997) studied the incidence of foliar and soil borne diseases of mulberry such as leaf rust, powdery mildew, leaf blight, root knot and root rot in Madanapalle and Chittoor of Andhra Pradesh, Hosur of Tamil Nadu and Malvalli and Chamarajanagar of Karnataka during the rainy season of 1994. Among them rust caused by *C. fici* was prevalent in all places.

2.6 Epidemiology

2.6.1 Spore Germination

Spore germination implies a change from an inactive to an actively growing condition. This is accomplished in most fungi by the formation of a germtube, which continued to elongate and ultimately led to the formation of vegetative body of the fungus. The various constituents of the substrate are known to influence spore germination of some species of fungi. Some species germinated well in distilled or tap water, while others required certain special nutrients such as sugar, salts or nitrogen sources (Lilly and Barnett, 1951).

Duggar (1901) demonstrated difference in species in their nutritional requirement for germination by placing spores in water, bean decoction, nutrient salt solution and sucrose solution. According to him, germination of uredospore of *Uromyces caryophyllinus* (Schr.) Wint was better in sucrose solution. Further, Mains (1917) using detached leaf cultures of corn infected with *Puccinia sorghi* Schw. found that corn rust developed on corn leaves only when carbohydrate source was supplemented in a mineral nutrient solution.

2.6.2 Influence of temperature on spore germination

Temperature is one of the important external factors which influenced germination. In rust fungi, apparently the influence of environment, especially temperature and humidity, on spore germination is

highly variable. For example, Johnson (1912) observed a wide variation in the germination of cereal rust spores with a temperature range of 7°C to 25°C. Uredospores of *P. purpurea* Cooke, germinated better between 26°C and 29°C than at 5°C (Soumini, 1949).

Misra and Prasada (1971) observed germination of uredospores of *Puccinia pennisetti* Zimm in between 8°C and 30°C and the germination was 100 per cent at 20°C. The spores did not germinate at 5°C and 35°C. The occurrence of rust disease in mulberry was severe during November to January, which gradually disappeared during March. Temperature of 22-24°C and high relative humidity above 70% were optimum for disease development (Coihoun, 1973).

The epidemiological studies on sunflower rust at Coimbatore have shown that a day temperature range of 25.5 to 30.5°C with a relative humidity of 86 to 92 per cent promoted greater rust intensity. The relative humidity was positively correlated with the incidence of rust (Hohan, 1978). In mulberry, the rust appeared immediately after the rainy season and reached the peak during August-September and prevailed upto February (Tomy Philip and Govindaiah, 1993). Disease in mulberry was higher during winter followed by rainy season (Sharma *et al.*, 1996).

2.7 Slow rusting components

Amount of inoculum in nature will determine the course of epidemic of any disease. In case of rusts, uredospores which are

responsible for development of disease, determine the rust epidemics. Threfore, number of uredospores produced on each pustule, pustule size and pustule number on leaves are the most important parameters in determining the resistance of varieties.

Kapoor and Joshi (1981) studied the slow rusting components in six susceptible wheat cultivars at seedling and flag leaf stge to race 122 of *Puccinia graminis* f. sp. *tritici* under glass house conditions. The cultivars, Sonalika produced fewer flecks and pustule / cm^2 than Agra local and Kharachia. The latent period for Sonalika was 1 to 2 days longer than for Kharchia and Agra local. Hence, they opined that lantent period and pustule density per unit area of leaf were the important components of slow rusting. Further, they observed similar kinds of results under glass house inoculation with same six cultivars in 1982.

Chandramouli (1982) studied the slow rusting phenomenon and components in cowpea cultivars against rust which indicated that latent period, number of pustules per cm^2 , size of the pustule and number of uredospores per pustule were the important components of slow rusting resistance in cowpea varieties *viz.*, V-16, V-70, TVX-944, V-37 and V-240 having recorded longer latent period, lower number of pustules per cm^2 of leaf area, smaller pustule size and lower number of uredospores per pustule, but the reverse trend was observed in fast rusting varieties *viz.*,C-152, HG-171 and in intermediates such as NPRC-1 and 3.

2.8 Biochemicals in disease resistance

Research on biochemical mechanism of resistance is predominant during the last two decades and is still being persued along with renewed emphasis on histology, including the use of chemical methods.

It was widely recognised that, the quantity of aromatic compounds such as mono and dihydroxy phenols, phenolic glucosides, flavonoides, anthocyanines, aromatic amino acids and caumarin derivaties were increased in host tissue invaded by a parasite. One of the major biological properties of phenolic compounds is their antimicrobial activity and it is often assumed that, their main role in plants is to act as protective compounds against disease causing agents such as fungi, bacteria and viruses.

Vidhyasekaran *et al.* (1974) working with rust of *Setaria italica* Beauv caused by *Uromyces setariae italicae* (Dict.) Yoshino concluded that low level of sugar conferred the host resistance and classified it as high sugar disease in comparison with wheat stem rust (Mclean *et al.*, 1961; Prabhu and Swaminathan, 1968). Involvement of phenolic compounds in many aspects of plant parasitic relationship other than plant protection has been reported (Friend, 1979).

The role of phenolics in the mechanism of disease resistance in plants has been reviewed by several workers (Walker and

Stahmann, 1955; Farkaŕ and Kiraly, 1962; Tomiyama, 1963; Klement and Goodman, 1967 and Rohringer and Sumborski, 1967). Concentration of phenolic compounds was usually higher in resistant than in susceptible genotypes of different crop plants (Arora and Wagle, 1985). Studies have also shown that, qualitative and quantitative changes in these compounds occurred after infection (Arora and Wagle, 1985 and Luthra *et al.*, 1988) with *Ramulispora sorghicola* on sorghum.

Chowdhury (1995) reported that non-conventional chemicals like Cyclohexamide, Cupric chloride, DL-phenyl alanine and Indole-3-acetic acid treated seeds of groundnut plants recorded higher levels of phenolics, proteins and oxidase activities in rust resistant groundnut varieties as compared to susceptible varieties. Behroozin *et al.* (1997) studied the changes in total phenolic content and its role in resistance in two cultivars of wheat against yellow rust and its role in resistance. The results showed a rapid increase in total phenolic content of inoculated leaves of resistant cultivar (MV-1) which was three times higher than susceptible cultivar (Bolani).

2.9 Evaluation of fungitoxicants

Use of fungicides is not only an alternate method of control of fig rust in the absence of resistant cultivar but an absolutely essential tool particularly when there is a sudden out break of the disease.

2.9.1 *In vitro* Evaluation

Benagi (1991) evaluated eight fungicides *in vitro* on uredospore germination of *Puccinia arachidis* and reported that Propiconazole, Tebuconazole, Chlorothalonil, Oxadaxil and Diclobutrazole were effective. Further, he tested fungicides in vivo and observed maximum reduction in per cent disease index with Propiconazole at 0.1%. Patil (1997) evaluated seven systemic and two non- systemic fungicides in vitro against uredospore germination of *P. helianthi*, casual agent of sunflower rust. Among systemic fungicides, Propiconazole, Hexaconazole, Cyperconazole and Tridemorph were found to be more effective even at the lower concentrations tested (0.025 and 0.05%) and among non systemic fungicides Mancozeb and Chlorothalonil were found effective at higher concentrations.

2.9.2 *In vivo* evaluation of fungicides

Rust of fig can be controlled to certain extent by the application of proper fungicides at definite intervals under field condition.

Hayes (1960) reported the use of Bordeaux mixture and Sulphur dusting to control fig rust.

Kulkarni and Sharma (1976) reported that Campogran. M, Plantavax and Benodanil were effective in checking the rust on fig leaves with initial infection, indicating their systemic and curative action. Similarly, the fig rust control with Bordeaux mixture, Sulphur and Zineb

been observed by various workers (Pathak, 1980 and Chundawat, 1990).

Rayachaudhari and Verma (1986) reported effective control of phalsa rust by 2 to 3 sprays of Mancozeb (0.2%). Similarly the fig rust caused by *C. fici* was effectively controlled by Mancozeb (0.2%), Tridemorph (0.1%) and San 619 (0.05%) followed by Propiconazole (Nazeer Ahmed *et al.*, 1993).

Gunasekhar *et al.* (1995) evaluated different fungicides *viz.*, Carbendazim, Captafol, Chlorothalonil, Mancozeb, Copper oxy chloride, Wettable sulphur at the rate of 0.1 and 0.2% concentrations on Kanava-2 mulberry genotype. Among them, Captafol, Chlorothalonil and Mancozeb were not only effective in reducing the disease incidence upto 49.54% and but also improved the leaf production.

Padule and Kaulgud (1994) reported the effective control of fig rust to the extent of 85.5 per cent by Chlorothalonil (0.2%) followed by Copper oxy chloride (0.4%). Similarly, two sprays of Captafol and Chlorothalonil at 0.2% reduced the leaf rust severity upto 50% and increased leaf yield by 28% on mulberry (Gunasekhar et al. 1995).

Desai and Jamadar (1997) reported effective control of fig rust by spraying Mancozeb (0.2%) at monthly intervals and there by reduced loss in fruit yield. Similarly, the fungicide, Mancozeb (0.2%) was effective in controlling fig rust under field condition. Other alternative

fungicides were *viz.*, Tridemorph, wettable sulphur and Chlorothalonil (Desai, 1998). Chandramouli *et al.* (1997) reported that Hexaconazole 5EC offered excellent control of coffee leaf rust (*Hemileia vastatrix* Berk and Branches.) disease @ 0.2% concentration and significantly superior to both Triadimefon and the conventional Bordeaux mixture. Similarly the combination product of Hexaconazole + Captan at 0.2% was highly effective with 83.3% reduction of grape rust disease over control. (Sharma *et al*, 1999).

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Studies on fig rust caused by *Cerotelium fici* (Cast) Arth. were carried out at the Department of Plant pathology, College of Agriculture, Raichur and Horticultural Farm, Regional Research Station, Raichur, Karnataka State during 1999-2000. Raichur, a district head quarters is situated in the Northern dry zone (zone-2) of Karnataka between 16° 15'N latitude and 77° 21' E longitude at an height of 389 meters above mean sea level with an average rainfall of 660mm. The mean maximum temperature of more than 30.0°C prevails through out the year. The relative humidity is high during months from June to October. The weather conditions prevailed during experimentation period between June 1999 to February 2000 are presented in Appendix-I. The materials used and the method followed during the course of investigations are presented hereunder.

3.1 Survey on the incidence of fig rust disease during 1999-2000.

An intensive fixed plot survery was conducted during August 1999 to Feb 2000 to know the incidence and severity of rust in the farmer's fields of Raichur, Koppal and Bellary districts. The survery was under taken in farmers fields in Gangavathi taluk of Koppal district and Hadagali taluk of Bellary district and Raichur taluk of Raichur district. The rust severity was recorded by following 0-5 scale given by Anonymous (1985).

Grade

0 No symptoms on the leaf

1 5% leaf area infected

2 5.1 to 10% leaf area infected

3 10.1 to 25% leaf area infected

4 25.1 to 50% leaf area infected

5 above 50% leaf area infected.

Per cent disease index (PDI) was calculated by using the formula given by Mc Kinney (1923).

$$\text{Per cent Disease Index} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves observed} \times \text{maximum grade}} \times 100$$

3.2 Epidemiology of fig rust

3.2.1 Effect of different incubation periods on germination of uredospores

Uredospore of *C. fici* were collected just by scraping the surface of pustules with clean stainless steel blade or needle. These spores were put on cavity slide with sucrose solution. The cavity slides were kept in the Petridishes lined with blotting paper and then incubated at room temperature (25 ± 1°C) at different time intervals. The per cent germination of uredospore was recorded after 1, 5, 9, 13, 17, 21, 24 and 48 hrs of incubation. Uredospores with the germtubes longer than the

uredospore diameter were considered as germinated ones and then per cent germination was worked out by observing at least 100 uredospores in each replication.

3.2.2 Effect of different sucrose concentration on germination of uredospores.

Uredospore of *C. fici* were collected just by scraping the surface of pustules with clean stainless steel blade or needle. These spores were put on cavity slide with 0.5, 1,2 and 3% concentrations of sucrose solution and distilled water. The cavity slides were kept in Petridishes lined with blotting paper and then incubated at room temperature (25 ± 1°C) for about 24 hrs. The per cent germination was worked out by observing 100 uredospores in each replication.

3.2.3 Effect of different temperature levels on the germination of uredospore

As the maximum germination was obtained after 24 hrs of incubation, this period was used for studying the cardinal temperature required for uredospore germination. The procedure followed was similar to the one explained earlier. The slides were incubated for 24 hrs at different temperature levels, *viz.*, 5°C, 15°C, 20°C, 25°C, 30°C and 40°C. Four replications were maintained for each temperature and per cent germination of uredospore was calculated.

3.2.4 Effect of different relative humidity levels on germination of uredospore

The procedure followed for studying the relative humidity requirement for spore germination was similar to the one explained earlier. The slides were incubated for 24 hrs at different relative humidity levels *viz.*, 66.8, 75.6, 82.9, 88.5, 96.1 and 100%. These relative humidity levels were maintained in dessicator using different concentrations of H_2SO_4.

H_2SO_4 per cent concentration	RH per cent at 25°C
0	100.0
10	96.1
20	88.5
25	82.9
30	75.6
35	66.8

Then per cent germination of uredospore was calculated. Four replications were maintained for each treatment.

3.2.5 Effect of weather parameters on disease development for prediction model study.

Effect of weather factors like temperature (maximum and minimum in °C), relative humidity (maximum and minimum in per cent)

and rain fall (mm) and number of rainy days on the incidence and development of rust was studied in the established fig orchard of Horticultural Farm, Regional Research Station, Raichur during 1999-2000, on two cultivars *viz*, Poona and Bellary. The experiment consisted of three replications. In each replication one plant per treatment and 20 leaves per plant were selected. The observations were made on disease incidence and severity starting from first day of its appearance till the end of the season at regular interval using 0-5 scale given by Anonymous (1985). The PDI was calculated by the formula given by the Mc. Kinney (1923).

The observations on independent variables viz., atmospheric temperature, relative humidity, number of rainy days and rainfall were monitored daily. The weekly averages of independent variables of previous week i.e., Seven days before scoring disease were used for correlation with that of dependent variable of the following week. The independent variables were regressed on the dependent variable using multiple regression analysis (MRA) technique to generate the equations and to derive R^2 value for accounting variability.

3.3 Components of slow rusting

The different components of slow rusting mechanism like latent period, number of pustules / cm^2, size of the pustule and number of uredospores per pustule were studied in laboratory.

3.3.1 Latent period

Number of days taken for the appearance of uredo pustules from the date of inoculation was recorded as latent period.

3.3.2 Uredial density

A window of 1 cm^2 was made from a card board label. This was placed on each sample leaf at four places avoiding midrib on each leaf. The number of uredia present in all the four squares were counted. The average uredia/cm^2 on each variety was obtained.

3.3.3 Uredium size

A known number of pustules from each sample leaf were selected at random from each variety. The size of the uredium was measured using micrometry. The area of the pustule was calculated and expressed in mm^2 .

3.3.4 Uredospores per uredium

The same known number of pustules used for measuring the size were also used for estimating the uredospore per uredium. With the help of a clean needle the spores were collected in 0.5 ml distilled water in watch glass. Thus obtained spore suspension was stirred uniformly with the help of a glass rod after adding a drop of tween 20 to the suspension to remove clumped spores if any. A drop of spore suspension

was taken on haemocytometer and cover slip was placed on it before observing under microscope. The number of spores per pustule was calculated by using the formula given by Pathak (1984).

3.4 Biochemical studies

3.4.1 Extraction of leaf material in alcohol

Leaf samples of healthy and diseased leaves were collected. Leaf material was extracted in ethanol as per the procedure followed by Jayapal and Mahadevan (1968) and clarified with saturated solution of lead acetate. The excess lead acetate was precipitated by the addition of sufficient quantity of saturated solution of disodium hydrogen ortho phosphate. The precipitate was reseparated by filtering the alcohol extract through whattman No. 1 filter paper and the filtrate was made up to a known volume of 80 per cent of alcohol. Reducing sugars, non reducing sugars, phenols and ortho-dihydroxy phenols were estimated in the alcohol extract of fresh leaves.

3.4.2 Estimation of total phenols

Estimation of total phenols present in plant samples was carried out by following Folin-Ciocalteau Reagent Method.

Reagents

1. Folin Ciocalteau Reagent (FCR) 1%
2. Sodium carbonate (2%).

Procedure

One ml of alcohol extract of fig tissue was taken in a test tube to which 1ml of Folin-Ciocalteau Reagent followed by 2ml of sodiumcarbonate solutions were added. The tubes were shaken well and heated in boiling hot water bath for exactly one min, and then cooled under running tap water. The blue solution was diluted to 25 ml with water and its absorbance was read at 650 nm in a spectrophotometer. The amount of phenol present in the samples was calculated from a standard curve prepared from catechol.

3.4.3 Estimation of ortho-dihydroxy phenol (Arnow's method)

Arnow's reagent specially reacts with ortho-dihydroxy phenols by producing a pink coloured complex and the intensity of which is measured in a colorimeter.

Reagents :

1. Arnow's reagent : 10g of sodium nitrite ($NaNO_3$) and 10 g of sodium Molybdate ($Na_2 MoO_4$) were dissolved in 100 ml distilled water.
2. 0.05 N-HCl
3. 1 N- NaOH.

Procedure

One ml of the alcohol extract was pipetted out in to a test tube to which 1 ml of 0.05 N HCl, 1 ml of Arnow's reagent, 10 ml of distilled water and 2 ml of 1 N NaOH were added. Soon after the addition

of NaOH, the contents of the test tube turned to pink colour. The intensity was read at 515nm in a spectrophotometer. The ortho-dihydroxyphenol content in the unknown samples were determined from the standard curve of catechol.

3.4.4 Estimation of soluble sugars

Reducing sugars from leaf samples were estimated by Nelson's modification of Somogy's method (Nelson, 1944). Non reducing sugars were hydrolysed using 1 ml of 1N-H_2SO_4 and then estimated as in the case of reducing sugar to get the total sugars. Non reducing sugars were calculated by subtracting the reducing sugar from that of total sugars.

3.5 *In vitro* evaluation of fungicides

Seven fungicides were evaluated under *in vitro* conditions by germination of uredospore of *Cerotelium fici*. Required concentrations of each fungicides was prepared using two per cent sucrose solution. Each concentration of a fungicide was replicated four times on a glass slide. List of fungicides used in the study are presented in Table 1. One hundred uredospores were observed 24 hours after incubation in a moist chamber. The per cent germination of uredospores was calculated in each case. A control treatment was also maintained with two per cent sucrose solution. Per cent inhibition over control was calculated using the formula given by Vincent (1927).

$$\text{Per cent inhibition} = \frac{C-T}{C} \times 100$$

Where,

C = Germination of uredospore in control

T = Germination of uredospore in treatment.

3.5.1 Spore germination study

The efficacy of seven fungicides was tested against *C.fici* by assessing percentage inhibition of spore germination. Single drop of uredospore suspension was added to the wells of series of cleaned cavity slides to which single drop of different fungicides was also added to get the required concentrations. Later, cover slip was placed on the cavity slide. Each concentration was replicated thrice on a separate cavity slide.

A control treatment was maintained with two per cent sucrose solution. These cavity slides were kept in the Petridishes lined with moist blotting paper and were incubated at room temperature. After 24 hours, observations were taken in ten microscopic fields for each slide and the total number of spores germinated in each microscpoic field was recorded.

The average count of four cavity slides (four replications) was found out, and the per cent inhibition of spore germination was calculated with the following formula given by Vincent (1927) for each fungicides.

$$\text{Per cent inhibition} = \frac{C-T}{C} \times 100$$

Where,

C - Number of spores germinated in control .

T - Number of spores germinated in treated cavity slides.

Table 1. List of chemicals used

Sl. No.	Treatments	Per cent Concentration			
	Non Systemic				
1	Mancozeb 75 WP (Manzate)	0.1	0.15	0.2	0.25
2	Wettable Sulphur 80 WP (Wettasul)	0.1	0.15	0.2	0.25
3	Chlorothalonil 75 WP (Kavach)	0.1	0.15	0.2	0.25
	Systemic				
4	Tridemorph 80% EC (Calixin)	0.025	0.05	0.075	0.1
5	Propiconazole 25 EC (Tilt)	0.025	0.05	0.075	0.1
6	Hexaconazole 5% EC (Contaf)	0.025	0.05	0.075	0.1
7	Triadimefon 25 WP (Bayleton)	0.025	0.05	0.075	0.1

3.5.2 *In vivo* evaluation of fungicides

A field experiment was conducted during August 1999 to Feb-2000 at Horticultural Farm, Regional Research Station, Raichur under irrigated condition in order to find out a suitable fungicide in controlling rust disease. The details of the experiment are presented below.

The efficacy of three non systemic fungicides (Mancozeb, Wettable sulphur, Chlorothalonil), four systemic fungicides (Tridemorph, Propiconazole, Hexaconazole, Triadimefon) and one untreated control were maintained. The chemicals were measured accurately just before spraying and mixed thoroughly with water.

The first spray was given on the appearance of the disease and was repeated at 20 days interval and severity was evaluated at 20 days interval. Supervisory/ need based Mancozeb spray (T_9) was undertaken whenever the disease increased in severity. The details of treatments are furnished below.

Treatment	Fungicides	Concentration (%)
T1	Mancozeb 75 WP (Manzate)	0.2
T2	Wettable Sulphur 80 WP (Wettasul)	0.3
T3	Chlorothalonil 75 WP (Kavach)	0.2
T4	Tridemorph 80% EC (Calixin)	0.1
T5	Propiconazole 25 EC (Tilt)	0.1
T6	Hexaconazole 5% EC (Contaf)	0.1
T7	Triadimefon 25 WP Bayleton	0.1
T8	Control	
T9	Need based / Supervisory spray of Mancozeb 75 WP (Manzate)	0.2

3.6 Design and layout

The experiment was laid out in a Randomised Block Design with three replications. The treatments were randomly allotted to plots.

Number of plants / treatment	:	One plant / treatment
Treatment	:	Nine
Spacing	:	3m x 3m
Variety	:	Poona.

3.7 Observations recorded

Rust incidence on fig (*Ficus carica* L.) was recorded by using 0-5 scale and then Per cent Disease Index (PDI) was calculated by using the formula given by Mc Kinney (1923).

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves observed} \times \text{maximum grade}} \times 100$$

3.8 Statistical Analysis

Statistical analysis was carried out as per the procedures given by Panse and Sukhatme (1967). Per cent data were transformed to arc sine values and analysed statistically.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the investigation on fig rust caused by *C.fici* are presented here under in the pages to follow.

4.1 Survey of rust incidence in fig

The fixed plot survey was conducted for four times in different areas of Raichur, Koppal and Bellary districts of Northern Karnataka during 1999-2000 to assess the incidence and severity of fig rust in farmer's fields under irrigated condition. The data pertaining to survey are presented in Table 2 and Fig. 1.

The fig rust was more severe in all three districts. The highest severity of rust was observed in Koppal district (58.97) followed by Bellary (50.75) and Raichur districts (30.65). Of the four surveys conducted at each location, the maximum disease severity was recorded in second and third survey which were undertaken during September and November respectively, the minimum was observed in first survey taken up during August. In Koppal district, Devi camp village, recorded maximum disease severity in the third survey (82.5%) followed by Gangavathi village (70.0%), where as Holagundi in Bellary district recorded 77.8 % severity followed by 69.2% in Hadagali and least in Adavinamallikere (59.2%).Raichur district recorded least severity of 45.4% in Yeragera and 27.70 % in Raichur.

Table 2. Survey on the incidence and severity of fig rust during 1999-2000 in three districts of Karnataka

Sl. No.	District / Taluks	Village	Date	Mean PDI	District Mean
1.	Bellary				
	Hadagali				
	1	Adavinammallikere	22/8/99	29.5	
			28/9/99	50.0	
			7/11/99	59.2	
			8/1/2000	30.0	
			Mean	42.17	
	2	Hadagali	22/8/99	37.7	
			28/9/99	50.6	50.75
			7/11/99	69.2	
			8/1/2000	50.0	
			Mean	51.87	
	3	Holagundi	22/8/99	44.2	
			28/9/99	62.4	
			7/11/99	77.8	
			8/1/2000	48.4	
			Mean	58.2	
2	Koppal				
	1	Gangavathi	20/8/99	42.0	
			26/9/99	56.4	
			6/11/99	70.0	
			9/1/2000	47.0	
			Mean	53.8	58.97
	2	Devi camp	20/8/99	45.28	
			26/9/99	68.5	
			6/11/99	82.6	
			9/1/2000	60.0	
			Mean	64.10	
3	Raichur				
	1	Raichur	19/8/99	13.4	
			2/10/99	20.8	
			14/11/99	27.7	
			26/12/99	30.0	
			Mean	22.97	30.65
	2	Yeragera	19/8/99	22.06	
			2/10/99	35.0	
			14/11/99	45.4	
			26/12/99	50.9	
			Mean	38.34	

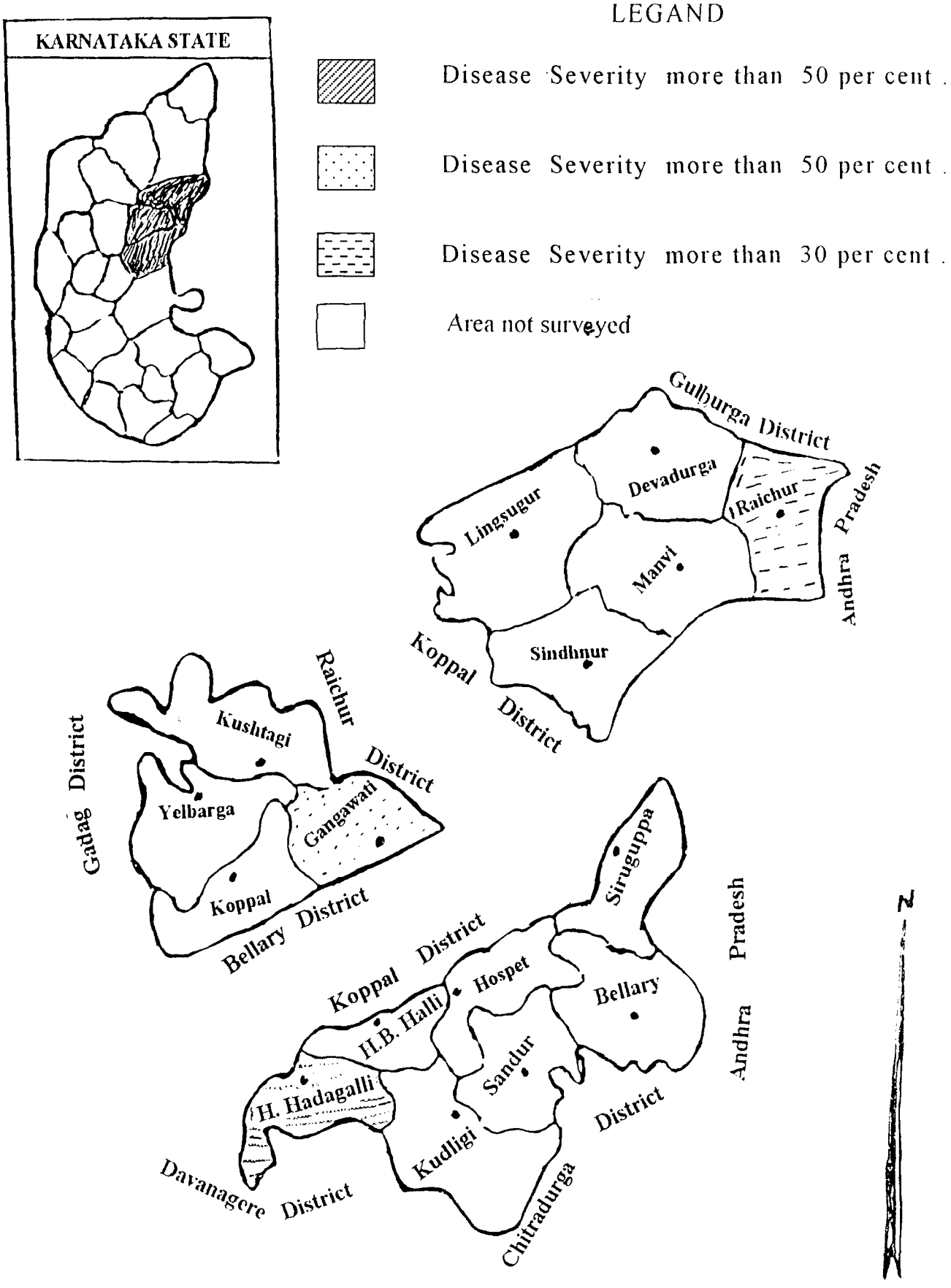

Figure 1. Map showing the severity of rust of fig in different taluks of three district of Northern Karnataka during 1999-2000.

Plate 1. Photograph showing the general view of experiments plot immediate after pruning.

Plate 2. Photograph showing the general view of experiments plot.

Plate 3. Photograph showing the symptoms of rust pustules on fig leaf.

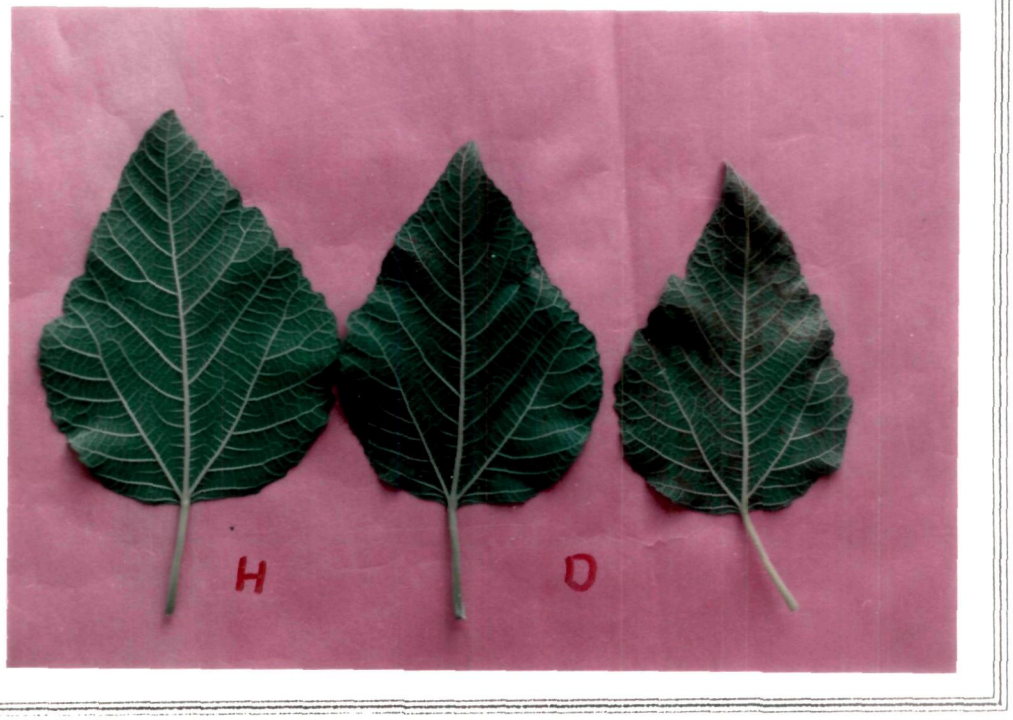

Plate 4. Photograph showing healthy and diseased fig leaf.

4.2 Epidemiology

4.2.1 Spore germination studies

Germination is an important process in the life cycle of pathogenic fungi, as host penetration and infection depend upon this vital process. More and quick germination also play a vital role in perpetuation of the species and spread of the disease.

4.2.2 Germination of uredospore at different incubation periods

The experiment was conducted to find out the optimum incubation period required for maximum uredospore germination. The observation on germination of uredospore was taken at different intervals following "standard procedures" and the results are presented in Table 3. and Fig.2.

The germination of uredospore started at 5 hours after incubation (7.55%) and attained the maximum at 24 hours after incubation (83.30%). Initially, the germination was not quite high till 9 hours of incubation and it remained around 21 per cent, subsequently the germination considerably improved to reach 57.8 per cent after 17 hours of incubation. However, the germination almost remained static after 24 hours of incubation and hence germination after 24 hours and 48 hours of incubation period were on par and significantly superior over other periods of incubation.

Table 3. Effect of different incubation periods on germination of uredospores of *C.fici.*

Sl.No.	Incubation period (hrs)	Per cent germination of uredospore
1	1.00	0.00* (0.00)**
2	5.00	7.55 (16.07)
3	9.00	21.00 (27.24)
4	13.00	33.30 (35.23)
5	17.00	57.80 (49.49)
6	21.00	75.00 (59.78)
7	24.00	83.30 (65.89)
8	48.00	84.20 (66.57)
	S.Em. ±	0.607
	CD at 1%	2.99

* Figures indicate original values

** Figures in the parentheses indicate Arc - sine transformed values.

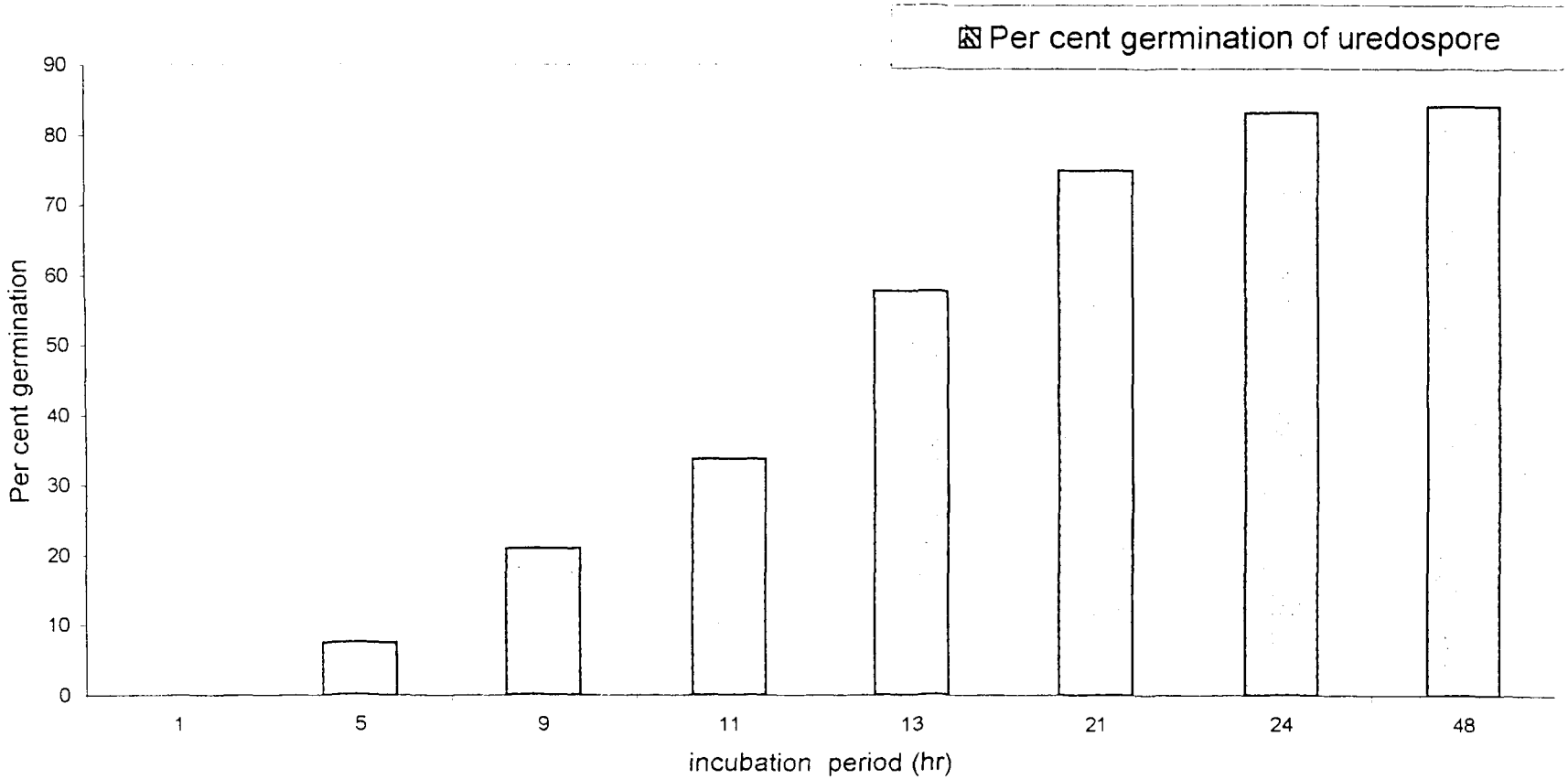

Fig. 2 Per cent germination of uredospore of *C. fici* in sucrose solution at diffferent incubation periods

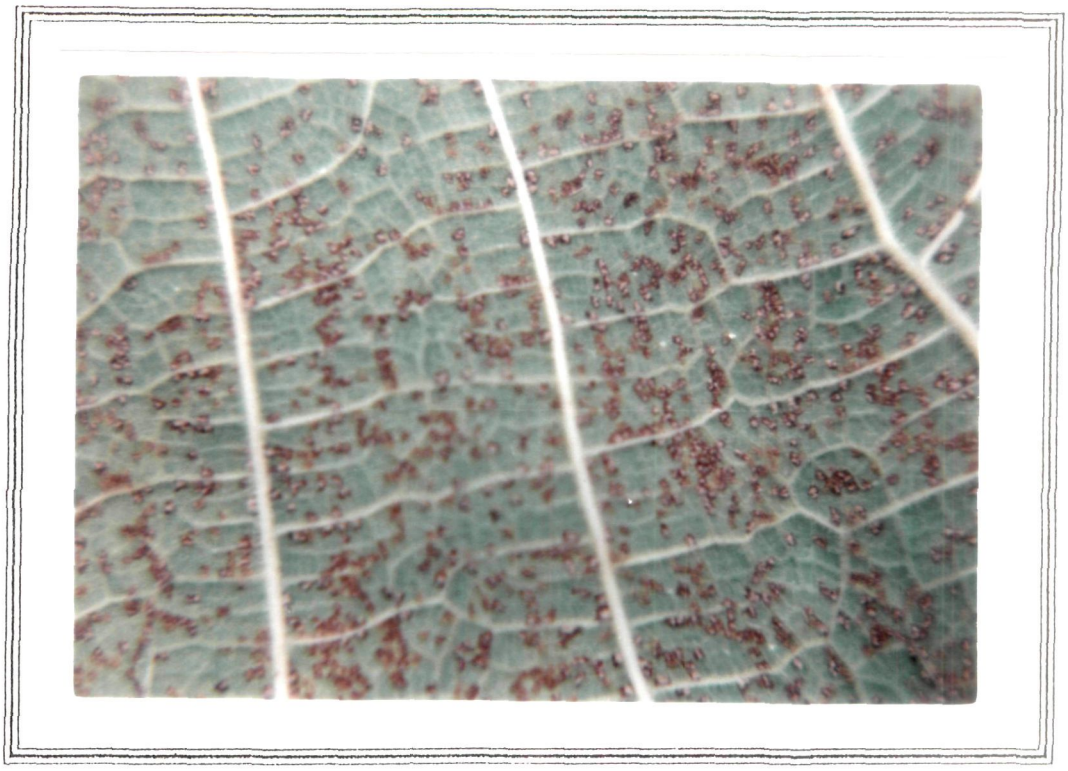

Plate 5. Photograph showing closeup view of uredial postules of *C.fici* on lower surface.

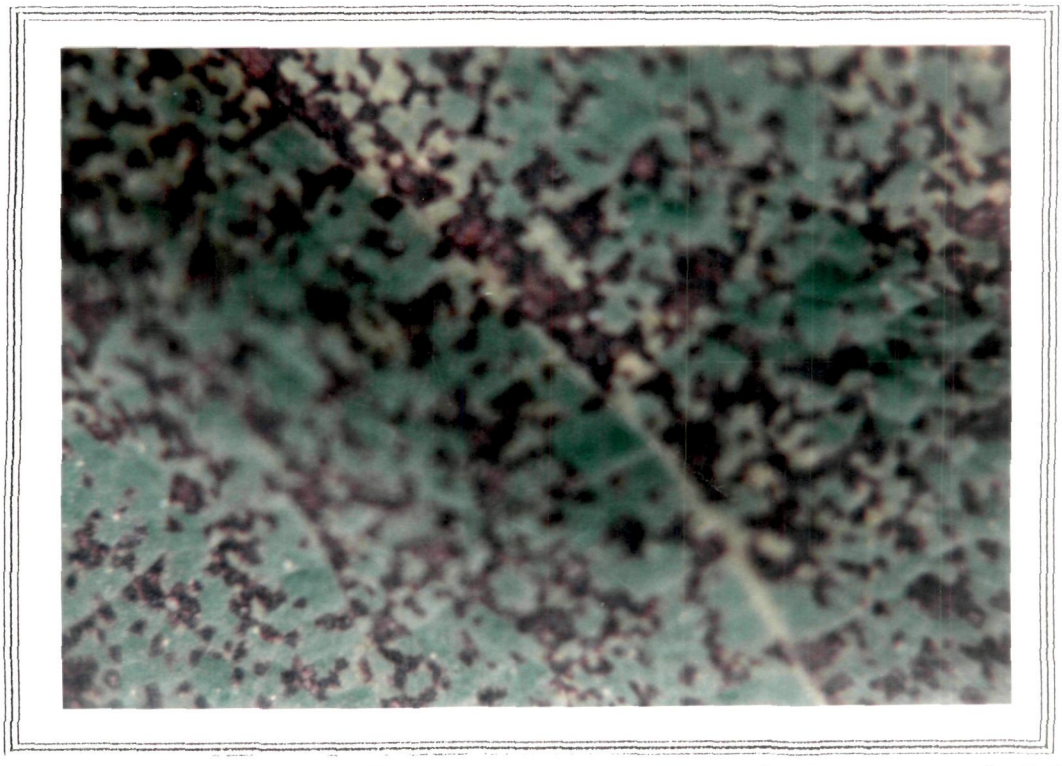

Plate 6. Photograph showing closeup view of uredial postules of *C.fici* on upper surface.

4.2.3 Germination of uredospore in different concentrations of sucrose

Uredospores require several ideal conditions, for germination such as substrate, temperature, relative humidity and others. In this experiment, the germination of uredospore in different concentrations of sucrose was studied and results are presented in Table 4 and Fig 3.

Germination reached maximum after 24 hours of incubation in all the treatments. The maximum per cent of spore germination (84.66 %) was recorded in three per cent sucrose solution and was on par with two per cent sucrose solution. The least germination was observed in distilled water (9.66%).

4.2.4 Effect of temperature levels on uredospore germination

Temperature is one of the important environmental factors which influences the germination of uredospore . The spores were incubated at 5°, 15°, 20°, 25°, 30° and 40°C for 24 hours in 2 per cent sucrose solution. The data are presented in Table 5 and Fig. 4.

Uredospore germination was significantly higher at 25°C (82%), followed by 30°C(80%). There was no germination at 5°C and the least was at 40°C. The percent germination of uredospore started declining suddenly when the spores were incubated at a temperature above 30°C. Temperature range of 25° - 30 °C was ideal for uredospore germination of *C. fici* and both were on par with each other.

Table 4. Effect of different concentration of sucrose on germination of uredospore of *C.fici* after 24 hours of incubation.

Sl. No.	Treatments	Concentration (%)	Per cent germination of uredospore
1	Distilled water	-	9.66* (18.10)**
2	Sucrose solution	0.5	34.00 (35.66)
3	Sucrose solution	1.0	58.00 (49.60)
4	Sucrose solution	2.0	84.00 (66.45)
5	Sucrose solution	3.0	84.66 (66.96)
	S.Em. ±		0.630
	CD at 1%		4.10

* Figure indicate original values.
** Figures in the parentheses indicate Arc – sine transformed values.

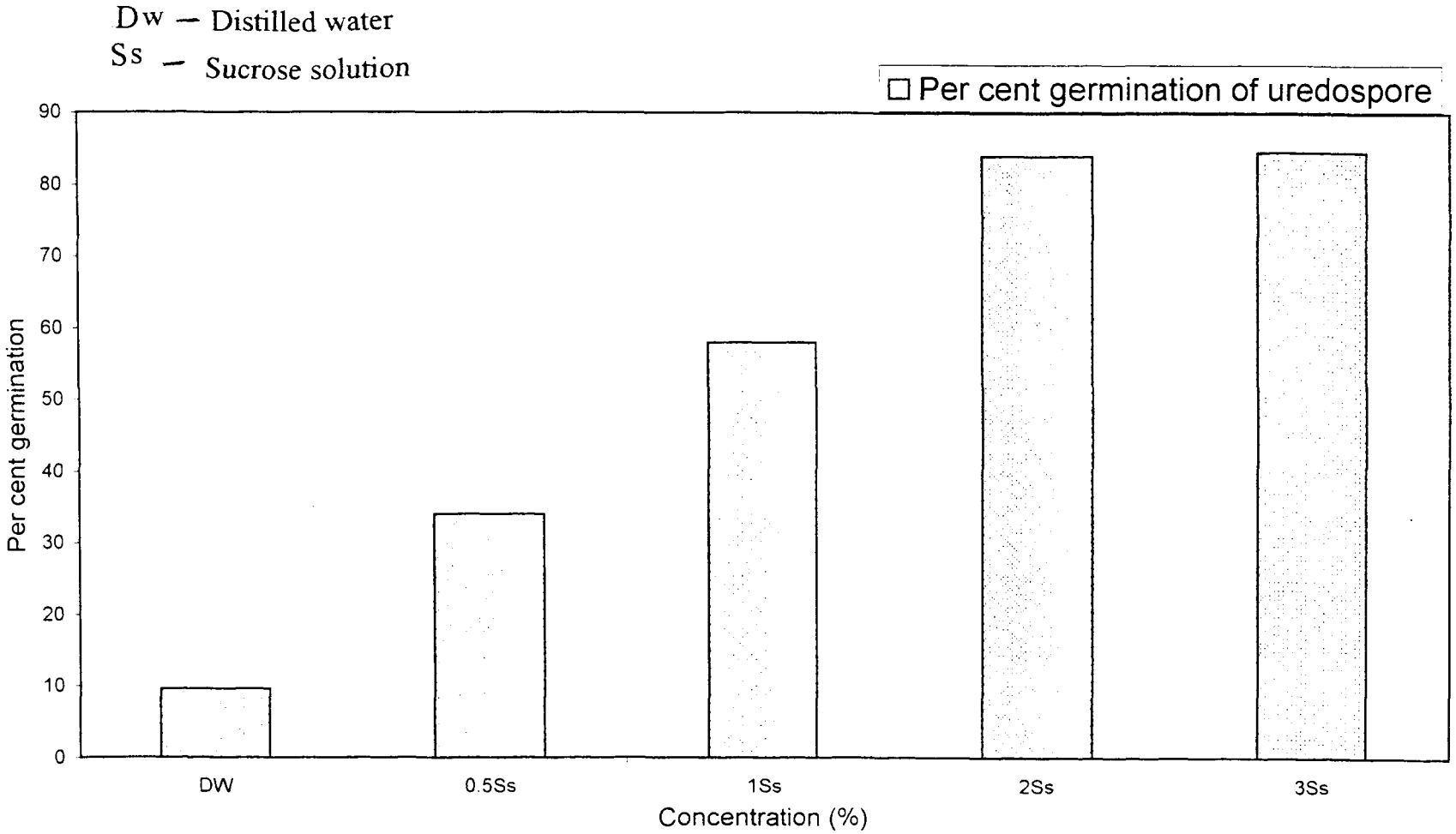

Fig. 3 Effect of different concentration of sucrose on germination of uredospore of *C.fici* after 24 hrs of incubation

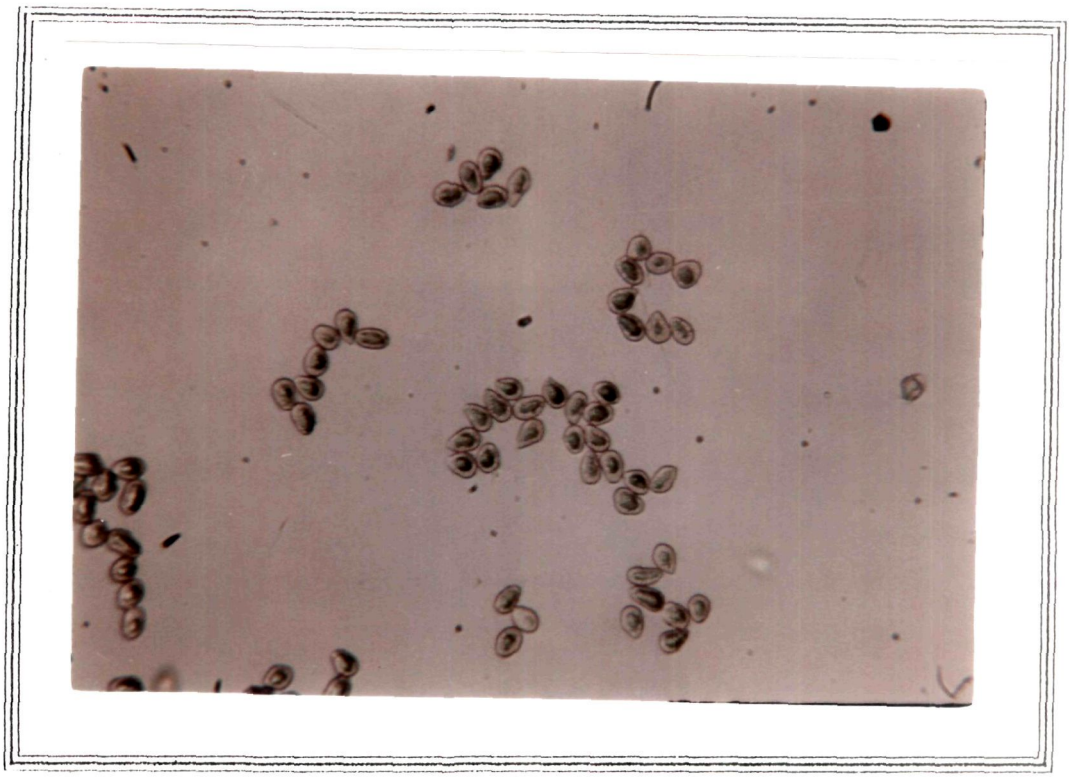

Plate 7. Microphotograph showing uredospore of *C. fici* (10x)

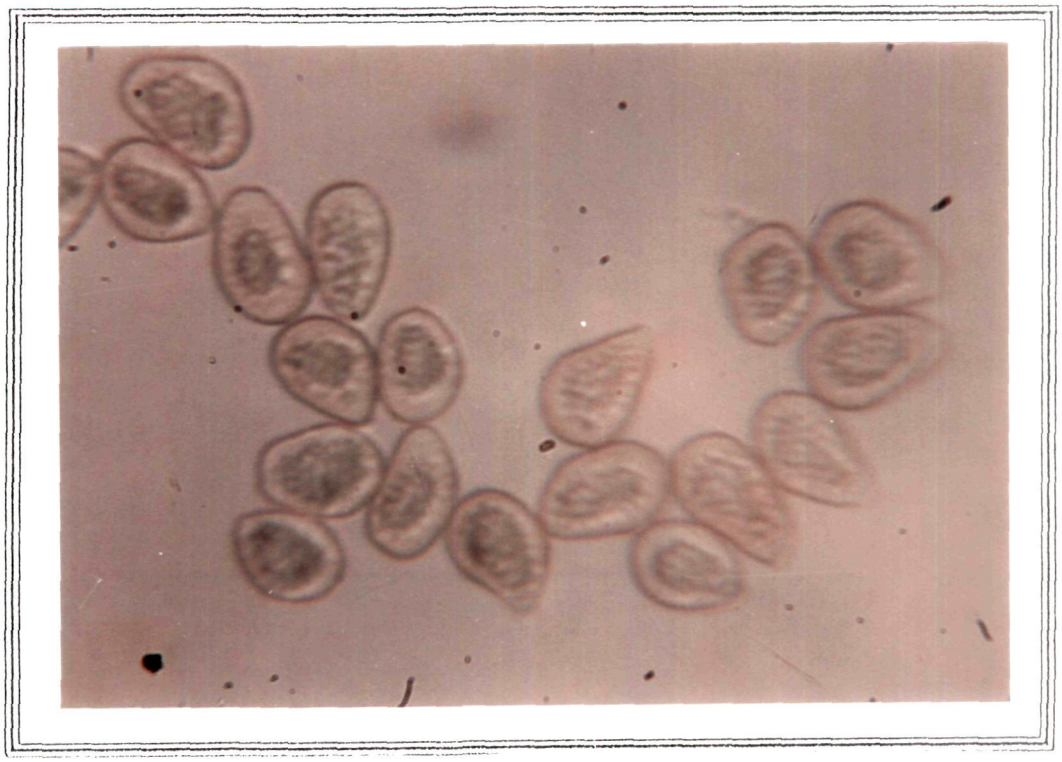

Plate 8. Microphotograph showing uredospore of *C. fici* (40x)

Table 5. Effect of different temperature levels on uredospore germination of *C. fici* after 24 hrs of incubation

Sl. No.	Temperature (°C)	Percent germination of uredospore
1	5	0.00 (0.00)
2	15	29.02* (32.54)**
3	20	36.44 (37.12)
4	25	82.00 (64.86)
5	30	80.00 (63.42)
6	40	8.00 (16.35)
	S.Em. ±	0.414
	CD at 1%	2.365

* Figure indicate original values.

** Figures in the parentheses indicate Arc – sine transformed values.

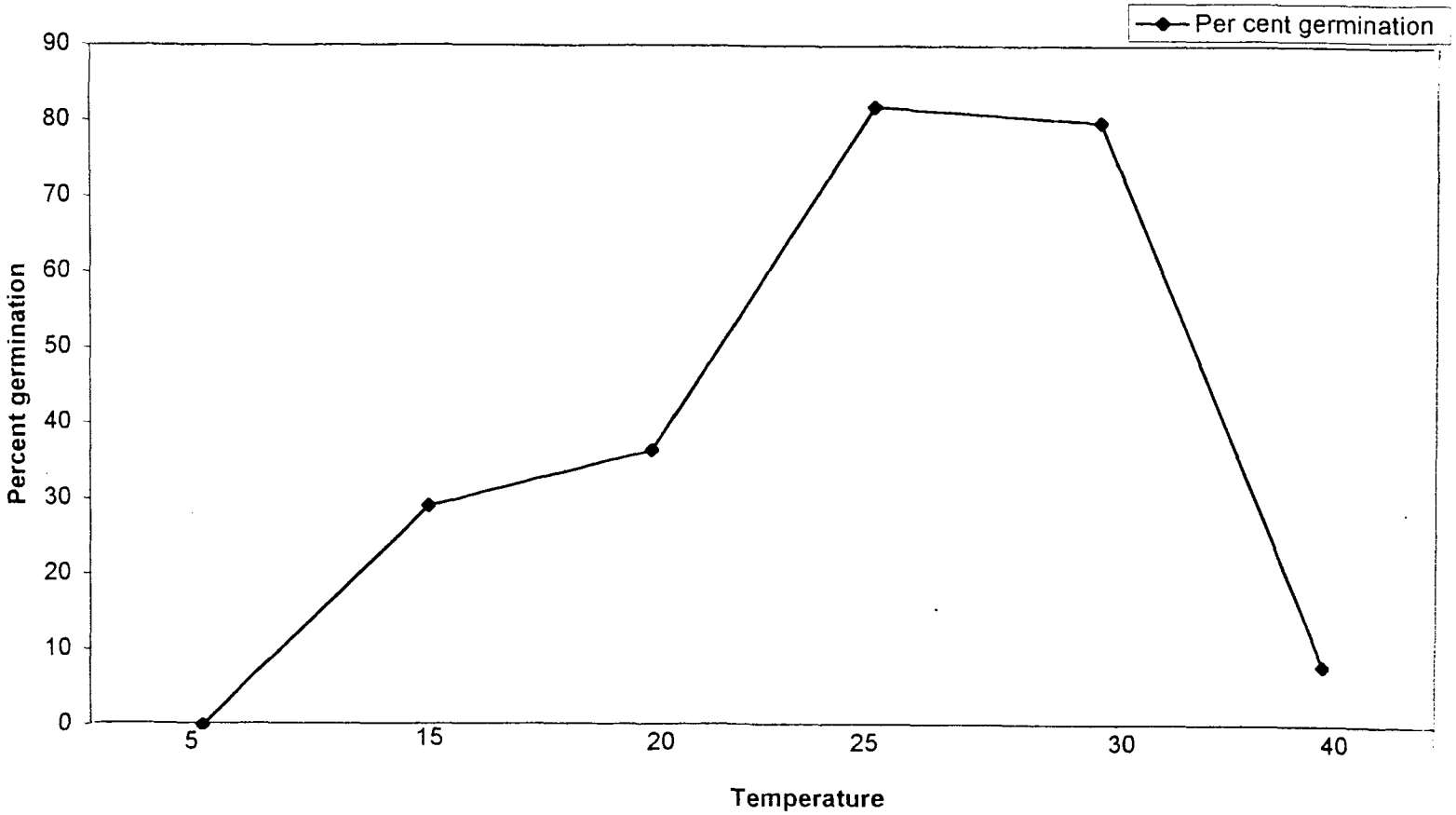

Fig. 4 Effect of different temperatrure levels on uredospore germination of *C. fici* after 24 hrs of incubation

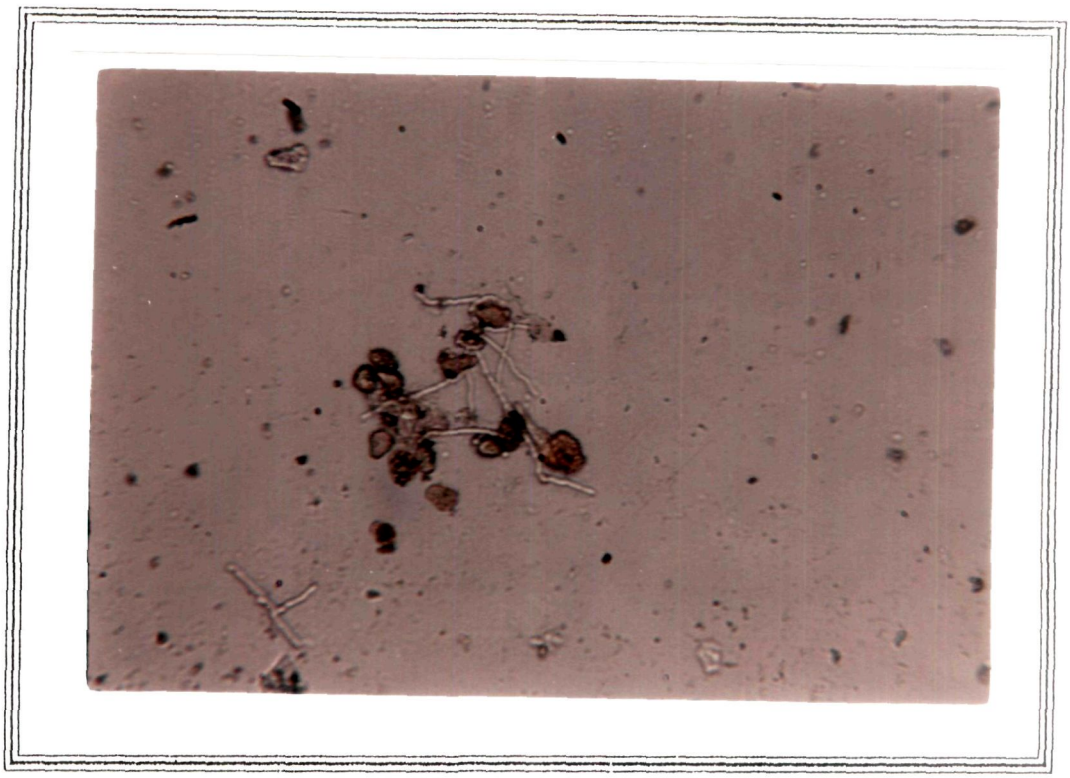

Plate 9. Microphotograph showing uredospore germination of *C. fici* (10x)

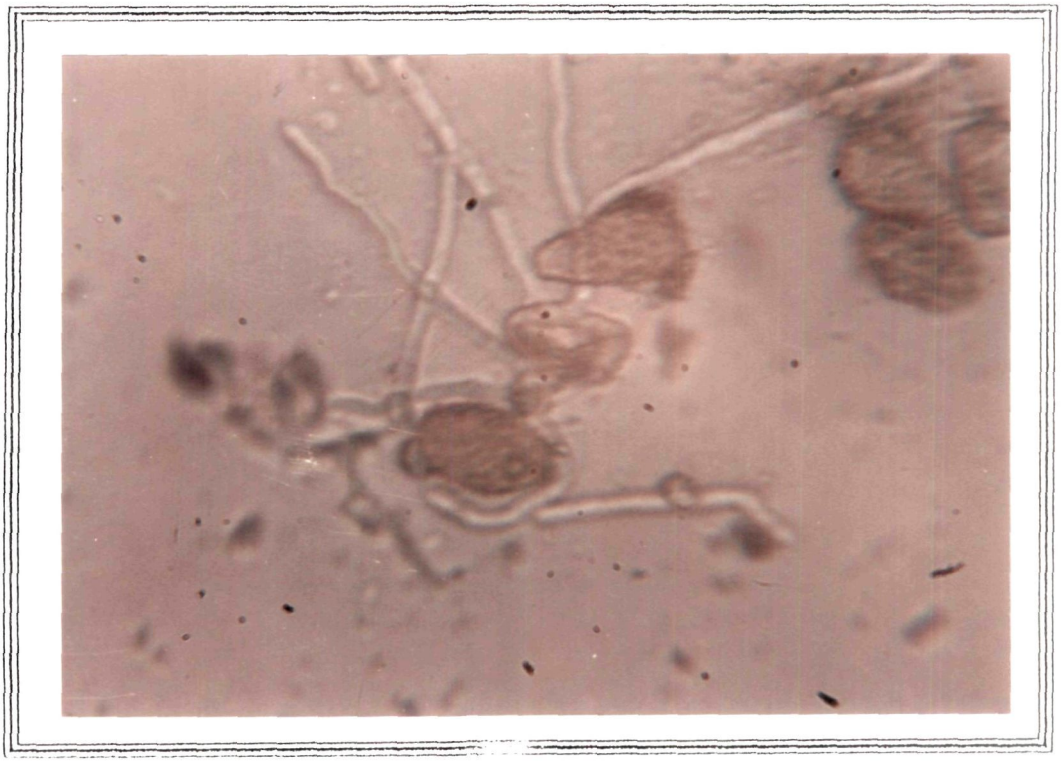

Plate 10. Microphotograph showing uredospore germination of *C. fici* (40x).

4.2.5 Effect of relative humidity levels on uredospore germination

Relative humidity (RH) is another important environmental factor which influences the germination of uredospores. The spores were incubated at different relative humidity levels *viz.*, 66.8, 75.6, 82.9, 88.5, 96.1 and 100 per cent for 24 hours in two per cent sucrose solution. The data are presented in Table 6 and in Fig. 5.

Uredospore germination was significantly high at 100 per cent RH (86%) and was on par with 96 per cent (85.33 %) and 88 per cent (85%) RH. The least germination was noticed at 66% RH (40.60%). The study revealed that, relative humidity in the range of 88-100 per cent was most suited for uredospore germination.

4.3 Effect of weather parameters in relation to development of fig rust.

Environment plays a decissive role in disease development when a vulnerable host and a virulent pathogen coincide in an ideal situation. Environment is the only variable that influences epidemic development. Therefore, weather parameters were used for relating to disease development studies in different combinations through correlation and regression. The role of weather factors on fig rust (*C. fici*) development was assesed during 1999-2000. Three randomely selected well established fig plants were pruned and intensity of the disease was recorded at weekly intervals as described in "Material and Methods". The weekly averages of weather parameters (Independent variable) *viz.*,

Table 6. Effect of different relative humidity levels on uredospore germination of *C.fici* after 24 hrs of incubation

Sl.No.	Relative humidity (%)	Percent germination of uredospore
1	66.8	40.60* (39.60)**
2	75.6	63.00 (52.53)
3	82.9	77.30 (61.56)
4	88.5	85.00 (67.25)
5	96.1	85.33 (67.48)
6	100	86.00 (68.03)
	S.Em ±	0.419
	CD at 1%	2.365

* Figure indicate original values.

** Figures in the parentheses indicate Arc – sine transformed values.

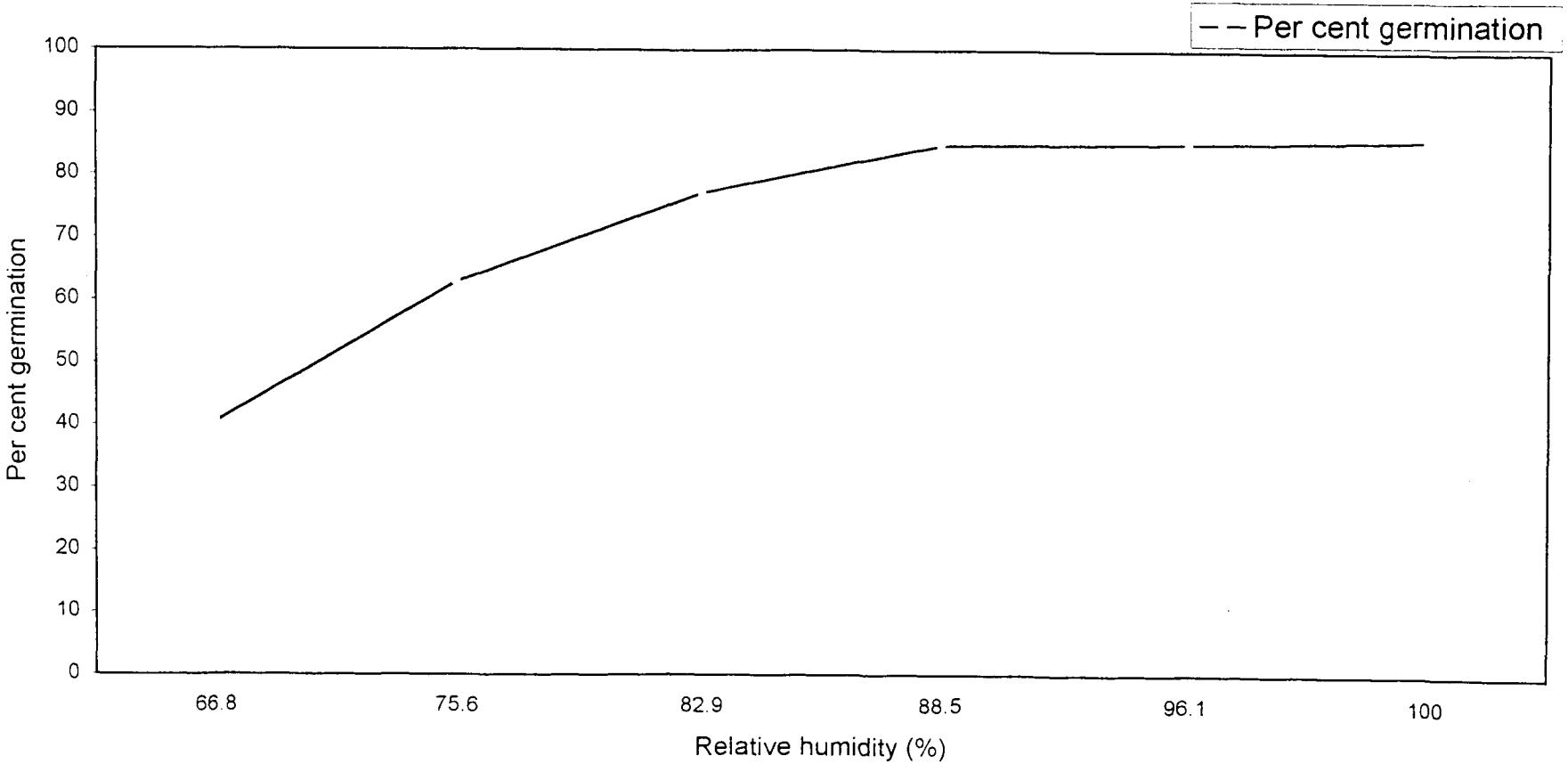

Fig. 5 Effect different relative humidity levels on uredospore germination of *C.fici* after 24 hrs of incubation

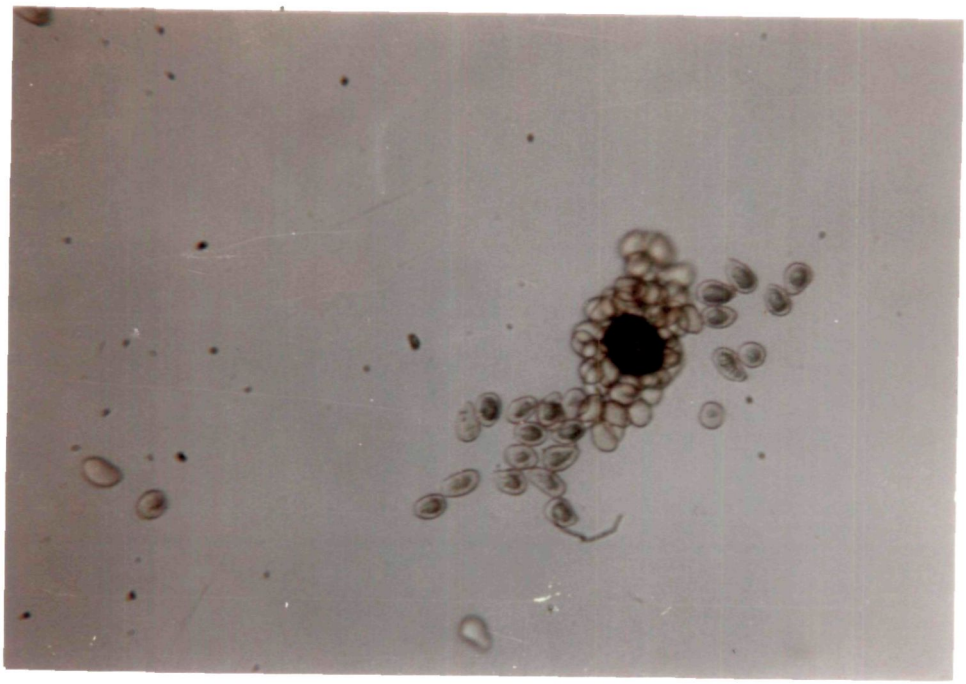

Plate 11. Microphotograph showing teliospores intermingled with uredospores of *C.fici* (10x)

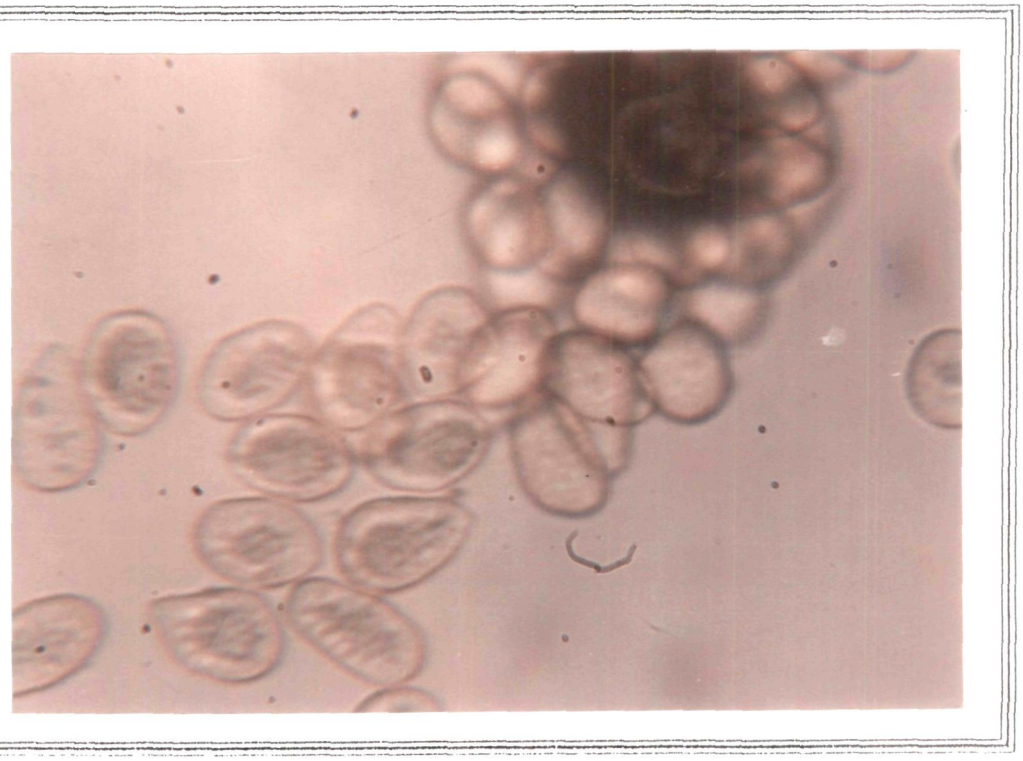

Plate 12. Microphotograph showing teliospores intermingled with uredospores of *C.fici* (40x)

maximum and minimum temperature, total rainfall, number of rainy days, maximum RH and minimum RH, of previous weeks were recorded and correlation and regression were worked out on disease incidence (dependent variable) of the following week and the data are presented in Table 7 and 8.

The Table 7 and 8 indicated that the disease started in traces after 28-30 days of pruning. The least per cent disease index of 10.6 per cent was noticed on 19th August, the beginning of the season during 1999. The PDI was 48 per centduring the end of the season on 27th January recorded during the 24th week's observation. The disease index reached its peak on 14th October with 83.4 per cent during the 9th week's observation. The high rust incidence of 66.4 to 83.4 per cent prevailed between 5th and 12th weeks observation, from the middle of September to the end of October. This period of maximum disease index, was characterized by maximum temperature range of 30.6 to 33.7°C and minimum of 17.47 to 23.4°C and maximum RH of 80.7 to 90%, and a minimum of 51.47 to 62.7 per cent RH. When the correlation was worked out between six independent variables (average of previous seven days) and dependent variable i.e., disease of the follwoing week, all six weather prameters indicated a positive correlation. Among them cumulative rainfall and cumulative rainy days are the two significant factors which showed high correlation co-eficient of 0.520 and 0.522 respectively. A perusal of data (Table 9,10,11,12,13, 14 and 15 and Fig. 6, 7, 8 and 9) on disease index

Table 7. Effect of weather parameters on rust development in Poona variety of fig during 1999-2000.

Average of seven days of previous week								
Sl. No.	Date	Max. Temp. (°C)	Min. Temp. (°C)	Cumulative rainfall (mm)	Cumulative rainy days (No.)	RH max. (%)	RH min. (%)	Mean PDI
1	19/8/99	33.6	22.6	5.7	1	81.6	53.7	10.6
2	26/8/99	31.5	23.5	25.15	4	86.8	67.1	18.8
3	2/9/99	30.7	22.0	30.95	8	92.1	65.6	38.6
4	9/9/99	31.4	21.9	38.15	10	89.6	63.4	55.7
5	16/9/99	30.6	21.8	38.95	11	87.1	57.4	66.4
6	23/9/99	33.7	22.0	40.09	12	80.7	51.47	70.4
7	30/9/99	33.1	23.1	46.59	15	87.3	53.4	75.4
8	7/10/99	32.1	23.4	47.36	16	87.4	62.7	73.6
9	14/10/99	32.8	23.04	55.30	18	85.4	59.3	83.4
10	21/10/99	32.1	21.3	56.01	18	90.0	57.4	71.6
11	28/10/99	32.6	22.12	60.71	20	84.4	53.4	67.6
12	4/11/99	32.8	17.47	60.71	20	81.0	32.8	69.4
13	11/11/99	33.7	21.0	60.71	20	80.9	41.1	63.0
14	18/11/99	32.0	14.7	60.71	20	80.60	25.14	54.6
15	25/11/99	31.07	17.0	60.71	20	77.6	36.7	53.6
16	2/12/99	31.8	18.0	60.71	20	84.3	38.7	55.0
17	9/12/99	30.8	16.2	60.71	20	77.9	32.14	55.6
18	16/12/99	30.0	14.2	60.71	20	73.0	33.0	56.0
19	23/12/99	29.8	15.2	60.71	20	79.1	33.3	56.4
20	30/12/99	30.8	17.1	60.71	20	85.0	35.6	52.6
21	6/1/00	29.6	16.0	60.71	20	75.2	34.1	48.6
22	13/1/00	31.34	17.98	60.71	20	79.2	35.0	45.4
23	20/1/00	34.18	18.08	60.71	20	75.14	24.57	48.6
24	27/1/00	34.12	17.5	60.71	20	62.74	26.00	48.0
Mean		31.93	19.45	60.71	20	81.84	44.71	56.01

Table 8. Correlation matrix for all the variables

Character	Temp. (°C)		R.F. (mm)	R.D. (No.)	R.H. (%)		PDI (%)
	Max.	Min.			Max.	Min.	
Max. Temp.	1.000						
Mln. Temp.	0.416	1.000					
R.F.	-0.131	-0.651	1.000				
R.D.	-0.088	-0.655	0.990	1.000			
Max. R.H.	-0.153	0.648	-0.431	-0.457	1.000		
Min. R.H.	0.008	0.891	-0.686	0.712	0.790	1.000	
PDI	0.059	0.089	0.520*	0.522*	0.187	0.055	1.000

* Significant at 5 % level

Temp - Temperature

R.H - Relative humidity

R.F - Cumulative rainfall

R.D.- Cumulative rainy days

with other weather parameters indicated that during August to October there was a greater increase in disease index and corresponding increase in cumulative rainfall and cumulative rainy days with high relative humidity which had influenced significantly on disease development. Hence, observations from number 1 to 9 which were identified as most crucial period were exclusively used for correlation which indicated 'r' value of 0.937 for cumulative rainfall and 0.956 for cumulative rainy days. When the variability was worked out using these two important factors on disease incidence an R^2 value of 0.878 was obtained with rainfall alone ($y=a+bx_1$, where a = -6.478, b = 1.704 and x_1 = cumulative rainfall, y = disease incidence) and an R^2 value of 0.914 was attained singly with rainy days alone ($y = a+bx_2$ where a = 7.362, b = 4.55, x_2 = cumulative rainydays, y = disease incidence) and combined effect of cumulative rainfall and cumulative rainy days contributed for an R^2 value of 0.915 ($y = a + bx_1 + bx_2$ where a = 4.897, bx_1 = 0.256, bx_2 = 3.9, x_1, x_2 = rainfall and rainy days respectvely, y = disease incidence). However, cumulative rainy days and rainfall combined with maximum ralative humidity accounted for an R^2 value of 0.918. When the variability was worked out using all the factors on disease incidence, R^2 value of 0.992 was obtained. Thus the best mathematic equations with high fitness were identified among them (Table 15) using the formula y = a + bx.

The observations from 16^{th} to 24^{th} i.e. starting from November to January were also exclusively observation were used for

Table 9. Effect of weather parameters on rust developments in Poona variety of fig during August - October 1999.

Observation		Average of seven days of previous week						
Sl. No.	Date	Max. Temp. (°C)	Min. Temp. (°C)	Cumulative rainfall (mm)	Cumulative rainy days (No.)	RH max. (%)	RH min. (%)	Mean PDI
1	19/8/99	33.6	22.6	5.7	1	81.6	53.7	10.6
2	26/8/99	31.5	23.5	25.15	4	86.8	67.1	18.8
3	2/9/99	30.7	22.0	30.95	8	92.1	65.6	38.6
4	9/9/99	31.4	21.9	38.15	10	89.6	63.4	55.7
5	16/9/99	30.6	21.8	38.95	11	87.1	57.4	66.4
6	23/9/99	33.7	22.0	40.09	12	80.7	51.47	70.4
7	30/9/99	33.1	23.1	46.59	15	87.3	53.4	75.4
8	7/10/99	32.1	23.4	47.36	16	87.4	62.7	73.6
9	14/10/99	32.8	23.04	55.30	18	85.4	59.3	83.4
Mean		32.17	22.59	36.48	10.56	86.44	59.31	55.43

Table 10. Correlation matrix for all the variable during August – October 1999.

Character	Temp. (°C)		R.F. (mm)	R.D. (No.)	R.H. (%)		PDI (%)
	Max.	Min.			Max.	Min.	
Max. Temp.	1.000						
Min. Temp.	1..280	1.000					
R.F.	-0.053	0.115	1.000				
R.D.	0.092	0.114	0.972	1.000			
Max. R.H.	-0.815	-0.082	0.239	0.132	1.000		
Min. R.H.	-0.734	0.212	0.001	-0.141	0.738	1.000	
PDI	0.021	-0.073	0.937*	0.956*	0.094	-0.260	1.000

* Significant at 5 % level

Temp - Temperature
R.H - Relative humidity
R.F - Cumulative rainfall
R.D. - Cumulative rainy days

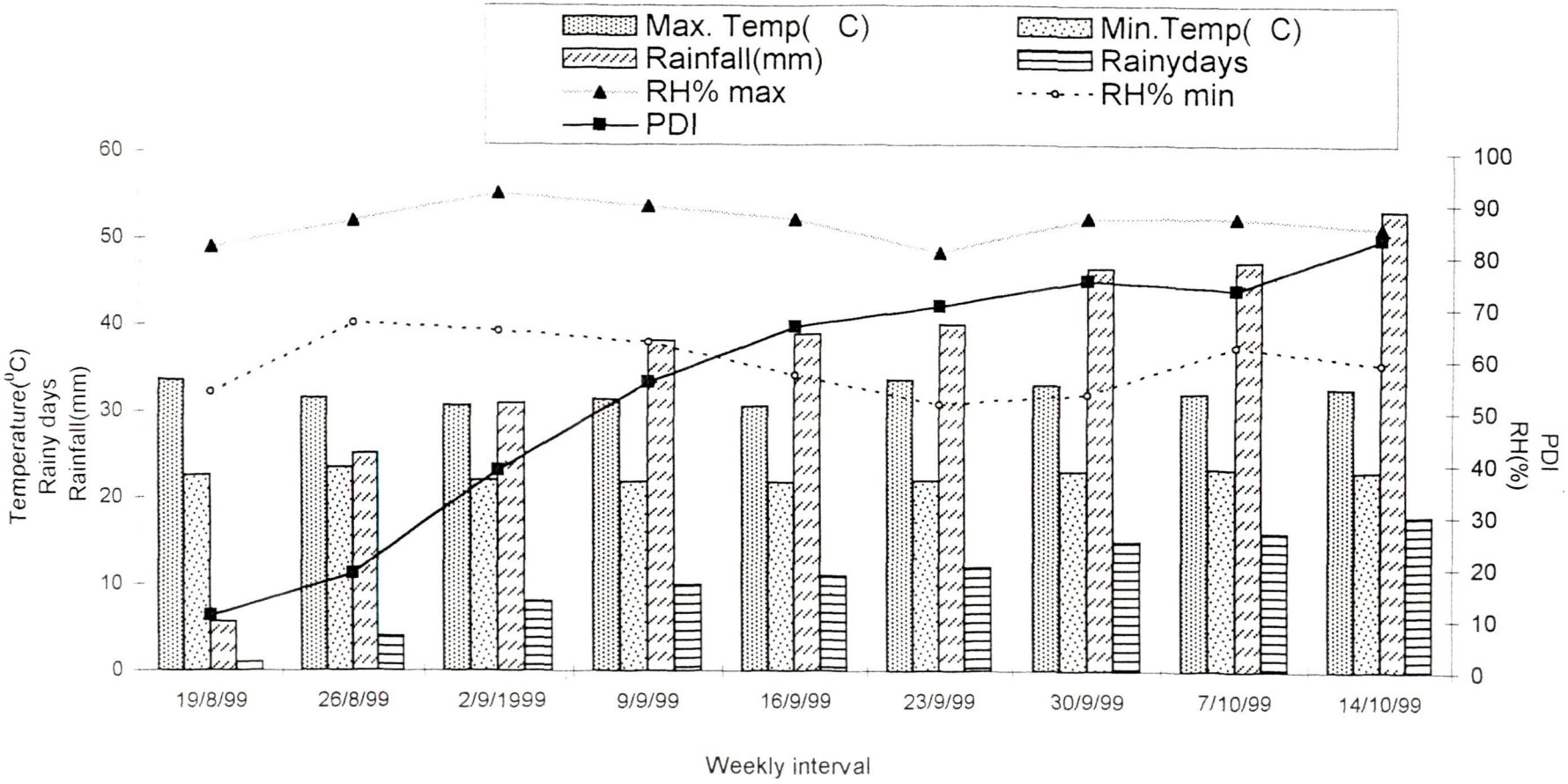

Fig.6 Effect of weather parameters on rust development in Poona variety of fig during August - October 1999

Table 11. Observed and Predicted severity of fig rust during August– October 1999 (for all the variables).

Case	Observed	Predicted
1	10.60	9.89
2	18.80	19.25
3	38.60	42.65
4	57.70	53.10
5	66.40	67.87
6	74.40	73.99
7	75.40	75.15
8	73.60	72.19
9	83.40	84.86

Coefficient of Determination (R-square) = 0.992

Multiple R = 0.996

Table 13. Effect of weather parameters on rust developments in Poona variety of fig during 1999-2000.

Observation		Average of seven days of previous week						
Sl. No.	Date	Max. Temp. (°C)	Min. Temp. (°C)	Cumulative rainfall (mm)	Cumulative rainy days (No.)	RH max. (%)	RH min. (%)	Mean PDI
16	2/12/99	31.8	18.0	60.71	20	84.3	38.7	55.0
17	9/12/99	30.8	16.2	60.71	20	77.9	32.14	55.6
18	16/12/99	30.0	14.2	60.71	20	73.0	33.0	56.0
19	23/12/99	29.8	15.2	60.71	20	79.1	33.3	56.4
20	30/12/99	30.8	17.1	60.71	20	85.0	35.6	52.6
21	6/1/00	29.6	16.0	60.71	20	75.2	34.1	48.6
22	13/1/00	31.34	17.98	60.71	20	79.2	35.0	45.4
23	20/1/00	34.18	18.08	60.71	20	75.14	24.57	48.6
24	2/1/00	34.12	17.5	60.71	20	62.741	26	48.0
Mean		31.38	16.67	60.70	20	76.83	32.51	51.73

Table 14. Correlation matrix for all the variables during November 1999–January 2000

Character	Temp. (°C)		R.F. (mm)	R.D. (No.)	R.H. (%)		PDI (%)
	Max.	Min.			Max.	Min.	
Max. Temp.	1.000						
Mln. Temp.	0.725	1.000					
R.F.	0.001	0.001	1.000				
R.D.	0.002	0.002	0.002	1.000			
Max. R.H.	-0.459	0.118	0.003	0.000	1.000		
Min. R.H.	-0.704	-0.151	0.001	0.001	0.745	1.000	
PDI	-0.508	-0.624	0.001	0.001	0.350	0.394	1.000

Temp - Temperature
R.H - Relative humidity
R.F - Cumulative rainfall
R.D. - Cumulative rainy days

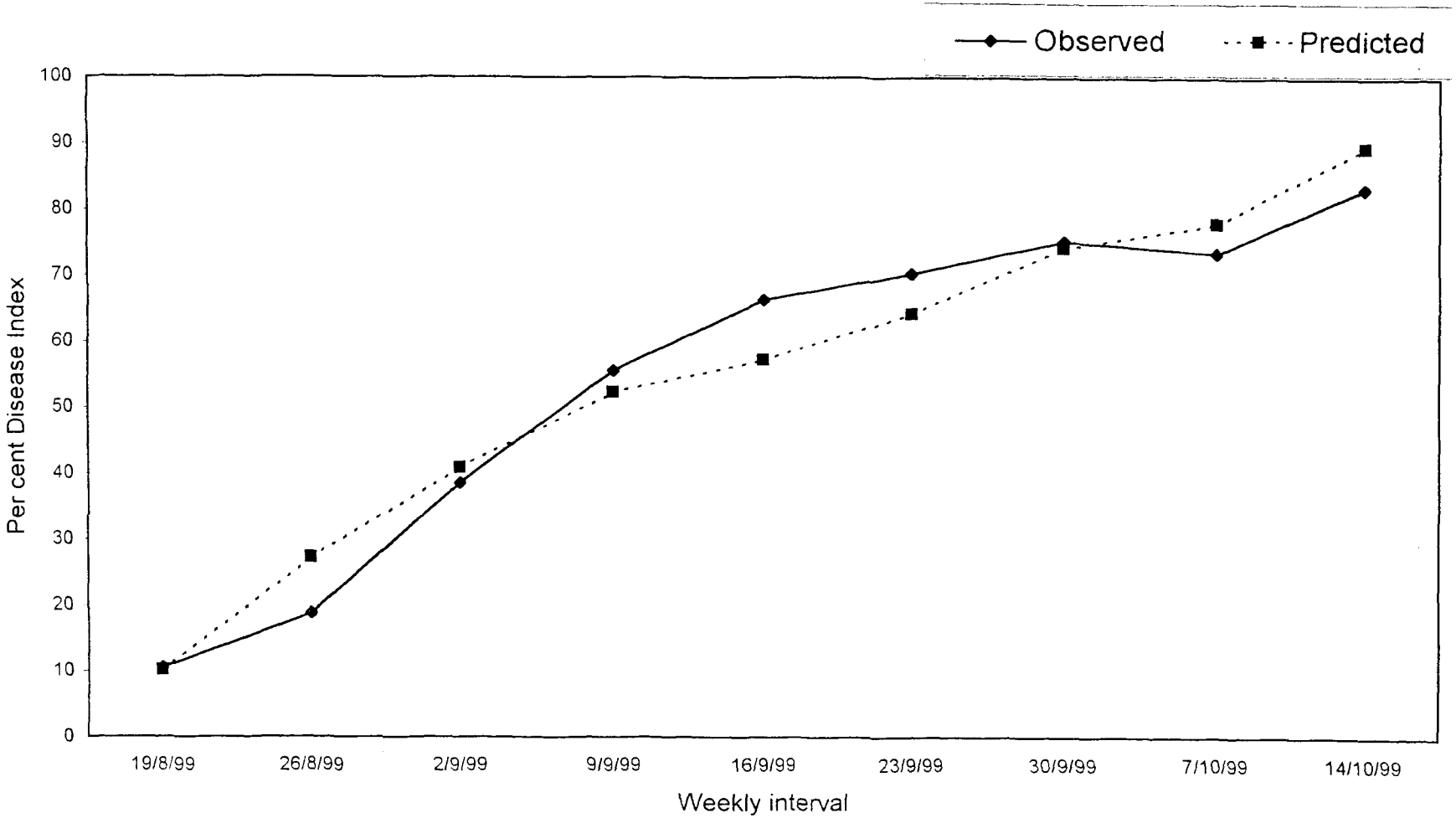

Fig. 8 Observed and predicted severity of fig rust during August - October 1999 (for three variables)

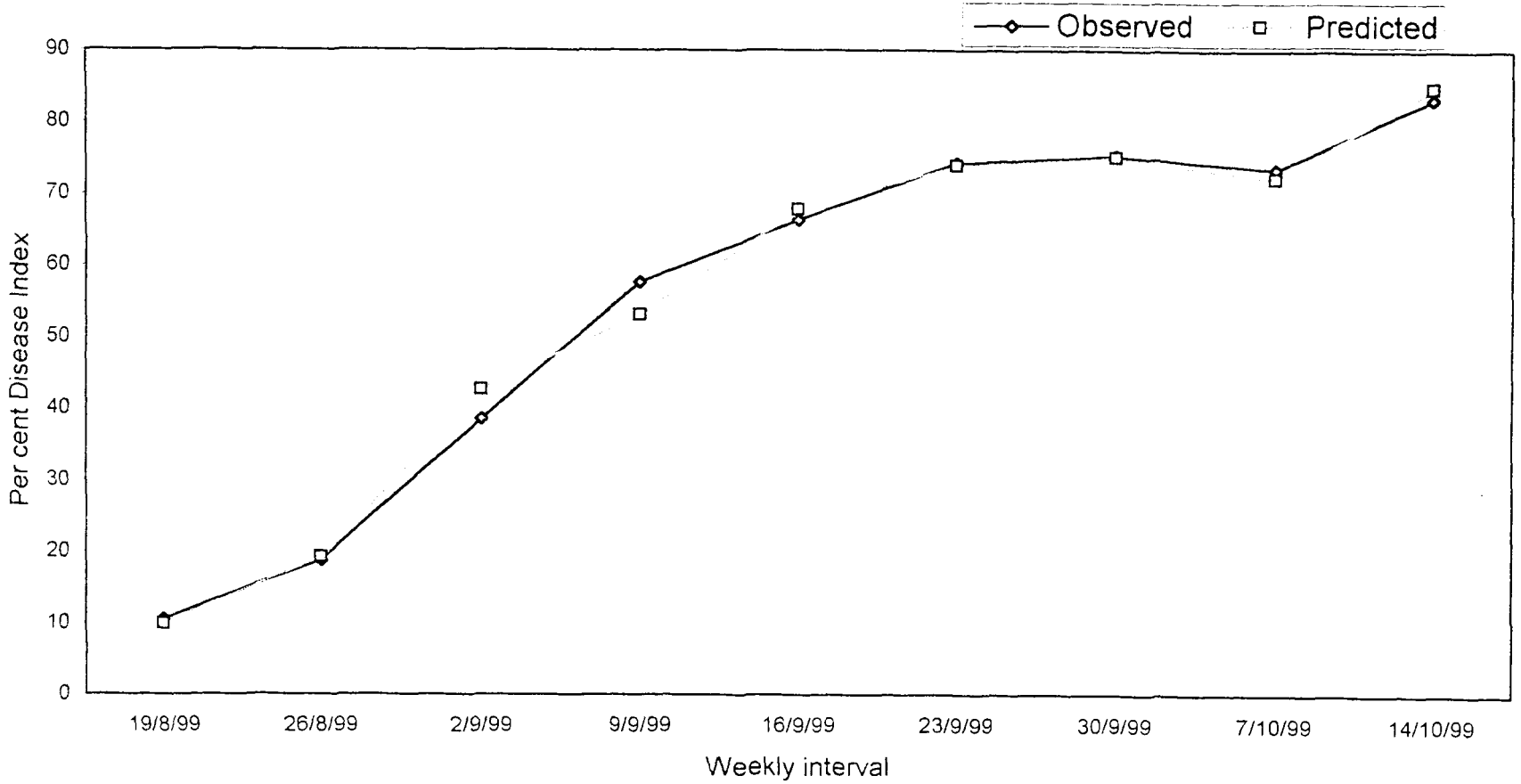

Fig. 7 Observed and predicted severity of fig rust during August - October 1999 (for all the variables)

Table 12. Observed and Predicted severity of fig rust during August - October 1999 (for three variable).

Case	Observed	Predicted
1	10.60	10.14
2	18.80	27.22
3	38.60	40.91
4	57.70	52.35
5	66.40	57.29
6	74.40	64.27
7	75.40	74.34
8	73.60	78.38
9	83.40	89.59

Coefficient of Determination (R^2) = 0.918

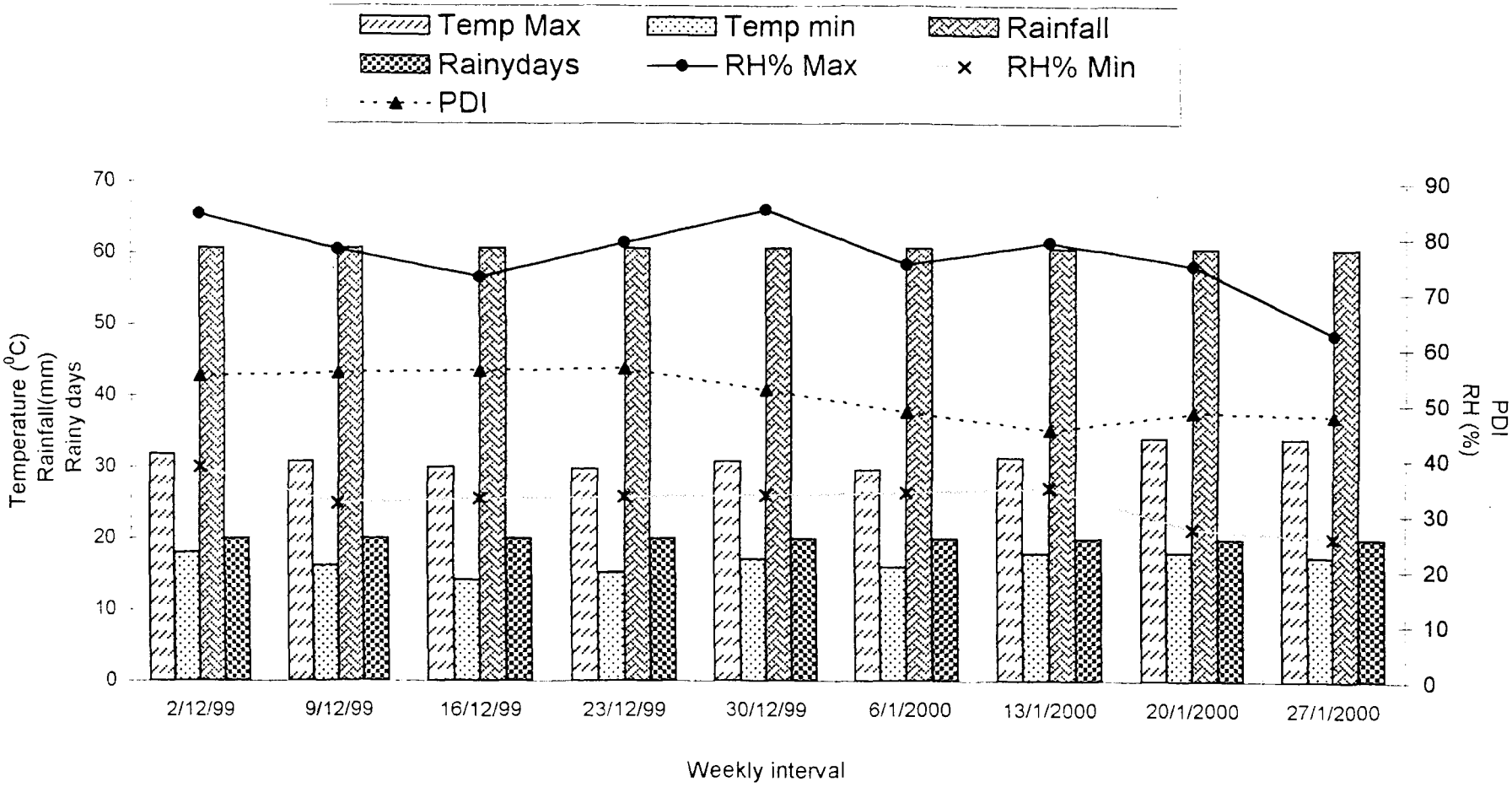

Fig. 9 Effect of weather parameters on rust development in Poona variety of fig during Nov 1999- Jan 2000

Table 15.Co-efficient of determination (R^2), constant (a), regression coefficient (b) values in multiple regression analysis in disease prediction model.

Equations	R^2 values
$y = -6.784 + (1.704 \times x_1)$	0.878*
$y = 7.362 + (4.55 \times x_2)$	0.914*
$y = 4.897 + (0.256x_1) + (3.90x_2)$	0.915*

* Significant at 5 % level

x_1 = Cumulative rainfall

x_2 = Cumulative rainy days

y = Disease incidence

analysis which was marked by the absence of rainy days and rain fall. The –ve correlation was seen with both minimum and maximum temperature with 'r' values –0.624 and –0.508. However, with maximum and minimum RH, the corresponding 'r' values were 0.350 and 0.394 respectively.

4.4 Slow rusting components

The different slow rusting components like AUDPC, latent period, uredia per square centimeter and uredospore per uredium were studied for fig varieties *viz.*, Poona and Bellary infected with *C.fici* as described under "Material and Methods" and the results are presented in Table 16.

4.4.1 Area under disease progress curve (AUDPC)

The AUDPC values were 9116.01 for Poona variety and 8815.94 for Bellary variety.

4.4.2 Latent period

Both Poona and Bellary varieties showed a latent period of 8-9 days.

4.4.3 Number of uredia per cm^2

The range of uredia number per square centimeter was 4.49 – 4.73 for Poona variety and 4.32 – 4.45 for Bellary variety .

4.4.4 Uredium size

The size of the uredium in Poona variety ranged from 0.115-0.194 mm^2 where as that of Bellary was 0.178-0.215 mm^2 .

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Table 16. Comparative values of slow rusting components of fig rust in two varieties.

Sl. No.	Varieties	AUDPC Values	Latent period (Days)	Uredia / (Cm^2)	Uredium size (mm^2)	Uredospore /Uredium
1.	Poona	9166.01	8-9	19.7-21.9 (4.49-4.73)	0.155-0.224	1500-2000
2.	Bellary	8815.94	8-9	18.2-20.0 (4.32-4.52)	0.178-0.215	1500-2500

4.4.5 Uredospores per uredium (UPU)

When the number of uredospores per uredium (UPU) were counted in two varieties *viz.*, Poona and Bellary, there was no variation between them. Uredospore per uredium both in Bellary and Poona varities was 1500-2500. The size of the uredospore ranged from 1-1.1 x 1.1-1μm in case of Poona and Bellary varieties without any variation.

4.5 Biochemical studies

4.5.1 Total phenol and ortho dihydroxy phenol content

The total phenol and ortho-dihydroxy phenol contents were estimated in healthy and diseased samples of both the varieties as per the "Material and method". The levels of total phenols and ortho-dihydroxy phenols were analysed both under healthy and diseased leaves of Poona and Bellary varieties. The results of the study are presented in Table 17. The amount of total phenolic and ortho-dihydroxy phenolic contents were higher in diseased sample of both the varieties *viz.*, Bellary and Poona as compared to healthy plants. The healthy samples of the same variety, Bellary recorded 1.938 mg /g of total phenols and 1.227 mg/g of ortho-dihydroxy phenols. The corresponding figures for diseased samples were 2.792 mg/g and 1.912 mg/g respectively. In case of variety Poona also the total phenols was 2.103 mg/g tissue and ortho-dihydroxy phenols was 1.090 mg/g in the healthy samples as against 2.784 mg/g and 1.594 mg/g in the diseased sample.

Table 17. Total phenols and ortho-dihydroxy phenolic content (mg/g of fresh leaf weight) in healthy and diseased fig leaf.

Varieties	mg/g of fresh leaf weight	
	Healthy	Disease
	Total phenols	
Bellary	1.938	2.792
Poona	2.103	2.784
	Ortho-dihydroxy Phenols	
Bellary	1.227	1.912
Poona	1.090	1.594

4.6 Sugar content

4.6.1 Total sugar content

There was a difference in the levels of total sugars in healthy and diseased leaves. Total sugar content was less in healthy compared to diseased leaves of both the varieties. The higher total sugar content was observed in diseased samples of Bellary variety (7.664 mg/g) and lower amount in healthy (4.438 mg/g) samples. Similar trend was noticed in case of Poona variety showing 7.36 mg/g in diseased sample as compared to 4.274 mg/g in healthy sample. The total sugar content was almost double in diseased sample to that of healthy sample in both the varieties.

4.6.2 Reducing sugar

Considerably higher amount of 4.025 mg/g of reducing sugar was observed in diseased sample of Bellary variety as compared to 3.143 mg/g in healthy sample. Similar trend was observed in Poona variety with diseased sample showing 4.0 mg/g and the healthy one recording 3.25 mg/g of reducing sugar. However, the reducing sugar content was more in diseased sample as compared to healthy in both the varieties.

4.6.3 Non reducing sugar

The non reducing sugar content was 3.639 mg/g in case of diseased sample of Bellary as against 1.295 mg/g in healthy

Table 18. Total sugar, reducing and non reducing sugar contents (mg/g of fresh leaf weight) in healthy and diseased fig leaf.

Varieties	mg/g of fresh leaf weight	
	Healthy	Disease
	Total sugars	
Bellary	4.438	7.664
Poona	4.274	7.360
	Reducing sugars	
Bellary	3.143	4.025
Poona	3.251	4.000
	Non – reducing sugars	
Bellary	1.295	3.639
Poona	1.023	3.360

leaves. The trend was similar in Poona variety with diseased sample showing 3.36 mg/g of non reducing sugar as against 1.023 mg/g in the healthy samples. By and large, the non reducing sugars were almost three times more in the diseased sample compared to healthy (Table 18).

4.7 Evaluation of fungicides

4.7.1 *In vitro* evaluation of fungicides

Efficacy of three non systemic and four systemic fungicides were tested at different concentration by assessing germination of uredospore of *C.fici* as explained in "Material and Methods". The observations were taken in ten microscopic (10x) fields, for each replication after 24 hours of incubation. The total number of uredospores prior to and after the germination in each microscopic field was recorded and the per cent germination was calculated. The data was subjected to angular transformations. Results relating to the effect of non-systemic and systemic fungicides on per cent inhibition of uredospore germination are presented in Table 19 and Fig. 10.

Among non-systemic fungicides, Mancozeb (Dithane M45) was found to be the best (77.37%) and significantly superior over other chemcials, Chlorothalonil (Kavach) was next best with 71.06 %followed by Wettable sulphur (42.43%). However, the maximum inhibition of spore germination was at 0.25 per cent concentration irrespective of fungicides. Mancozeb at 0.25 per cent concentration

Table 19. Effect of non systemic fungicides on per cent inhibition of germination of uredospore of *C. fici*.

Sl.No.	Treatments	Per cent Concentration				
		0.1	0.15	0.2	0.25	Mean
1	Chlorothalonil	63.48*	68.32	71.42	81.05	71.06
		(52.76)**	(55.77)	(57.62)	(64.22)	(57.96)
2	Mancozeb	71.42	74.60	79.36	84.12	77.37
		(57.74)	(59.75)	(62.98)	(66.54)	(61.75)
3	Wettable Sulphur	25.39	36.50	47.53	60.31	42.43
		(30.23)	(37.16)	(43.58)	(51.04)	(40.50)
	Mean	53.43	59.80	66.11	75.16	63.62
		(46.91)	(50.89)	(54.73)	(60.60)	(53.28)
		S.Em. ±		CD at 1 %		
Fungicides (F)		0.301		1.199		
Concentrations (C)		0.347		1.384		
Interaction (F x C)		0.602		2.398		

* Figures indicate original values

** Figures in the parentheses indicate Arc-sine tansformed values

Fungicides – Test significant at 1% level.

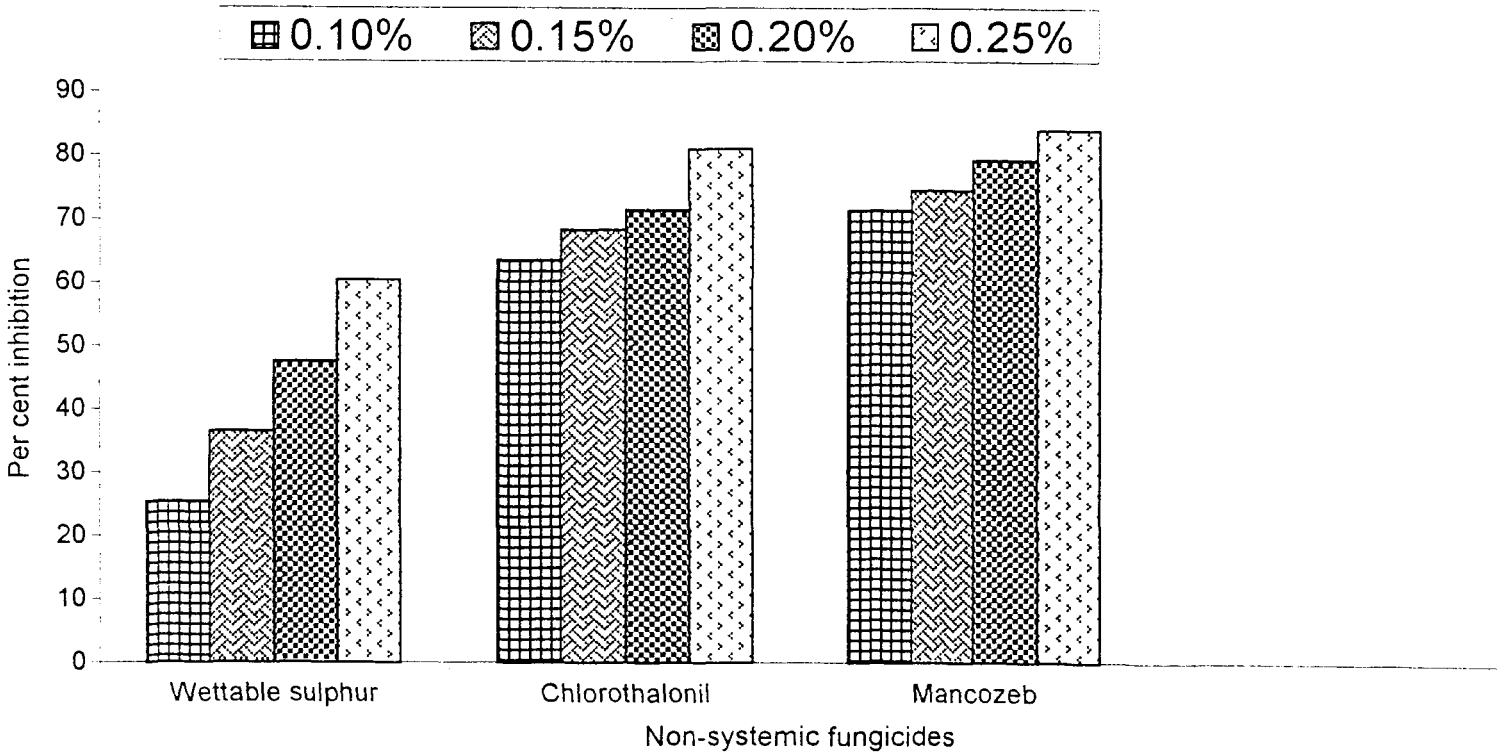

Fig.10 Effect of non- systemic fungicides on per cent inhibition of germination of uredospores of *C.fici*

inhibited 84.12 per cent spore germination followed by Chlorothalonil (81.05%) and Wettable Sulphur (60.31%) as compared to other concentrations. The corresponding figures at 0.2 per cent concentration were 79.36 , 71.42 and 47.53 per cent for Mancozeb, Chlorothalonil and Wettable sulphur respectively.

Inhibition of germination of spore by different systemic fungicides at different concentrations was studied. Results (Table 20 and Fig. 11) revealed that fungicides, concentrations and their interaction differed significantly with respect to per cent inhibition of germination of uredospore of *C.fici*. Hexaconazole was significantly superior with 91.27 per cent inhibition followed by Propiconazole with 89.42 per cent and Tridemorph with 79.75 per cent inhibition. Triadimefon (36.84% inhibition) which was found to be least effective in inhibition. However, with the increase in the concentration of these systemic fungicides from 0.025 to 0.1 per cent, there was an increase in the inhibition of spore germination . Among different concentrations, Hexaconazole at 0.1% showed maximum inhibition of spores (98.4%) which was on par with Propiconazole (96.80%) and followed by Tridemorph (90.46 %).

4.7.2 *In vivo* evaluation of fungicides

Efficacy of these systemic and non systemic fungicides were tested on fig rust under field conditions using the best concentration identified under in vitro. Totally five sprays were imposed at 20 days

Table 20. Effect of systemic fungicides on per cent inhibition of germination of uredospore of *C. fici.*

Sl.No.	Treatments	Per cent Concentration				
		0.025	0.05	0.075	0.1	Mean
1	Hexaconazole	82.53*	90.46	93.70	98.40	91.27
		(65.31)**	(72.39)	(75.57)	(85.78)	(74.76)
2	Propiconazole	80.95	85.71	93.62	96.80	89.42
		(64.22)	(67.97)	(75.57)	(80.89)	(72.16)
3	Tridemorph	66.66	76.18	85.71	90.46	79.75
		(54.77)	(60.85)	(67.97)	(72.39)	(63.99)
4	Triadimefon	23.80	28.56	45.83	49.2	36.84
		(29.12)	(35.58)	(42.60)	(44.54)	(37.46)
	Mean	63.48	70.22	79.71	83.71	74.32
		(53.36)	(58.69)	(65.43)	(70.90)	(62.09)

	S.Em. ±	CD at 1 %
Fungicides (F)	0.409	1.59
Concentrations (C)	0.409	1.59
Interaction (F x C)	0.818	3.18

* Figures indicate original values

** Figures in the parentheses indicate Arc-sine tansformed values

Fungicides – Test significant at 1% level.

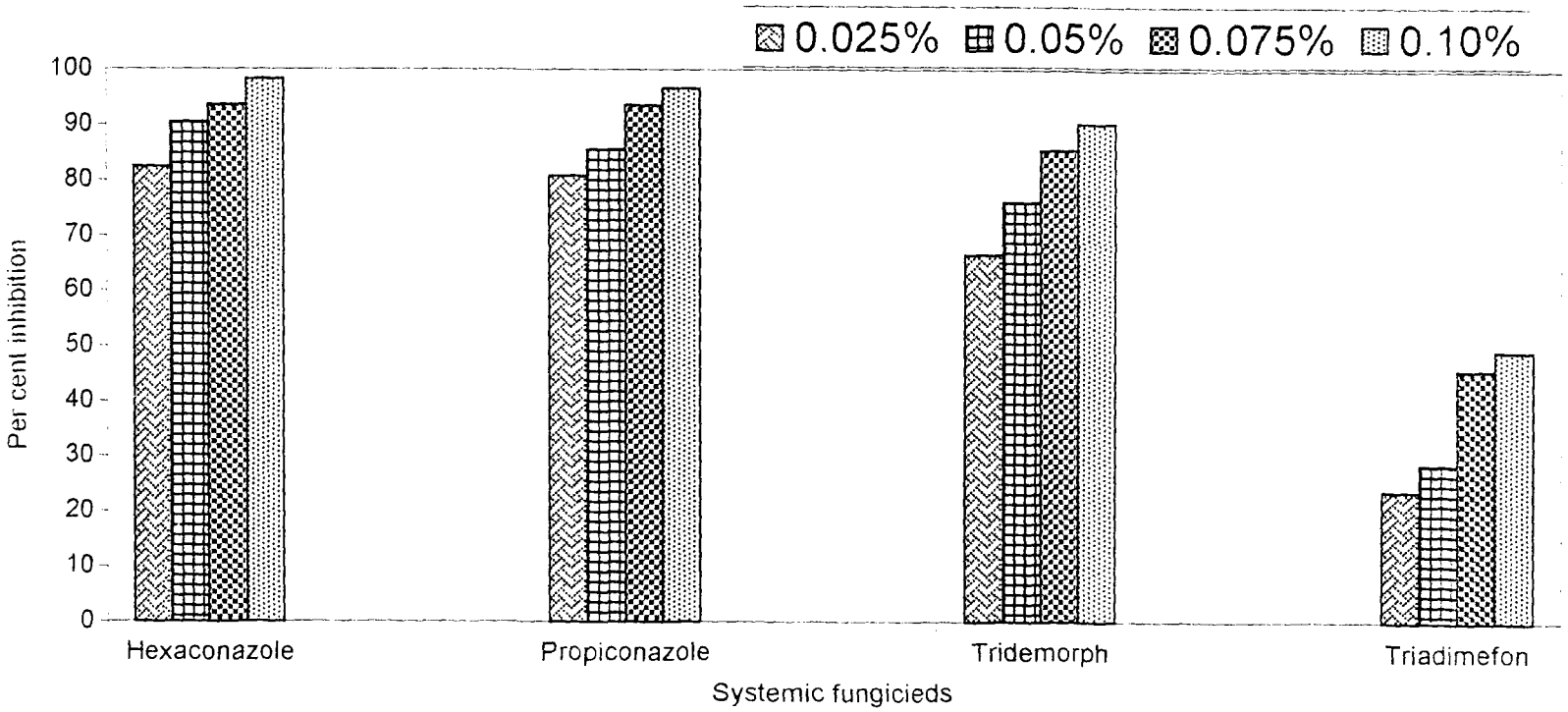

Fig.11. Effect of systemic fungicides on per cent inhibition of germination of Uredospores of *C.fici.*

Grade	
0	No symptoms on the leaf
1	5% leaf area infected
2	5.1 to 10% leaf area infected
3	10.1 to 25% leaf area infected
4	25.1 to 50% leaf area infected
5	above 50% leaf area infected.

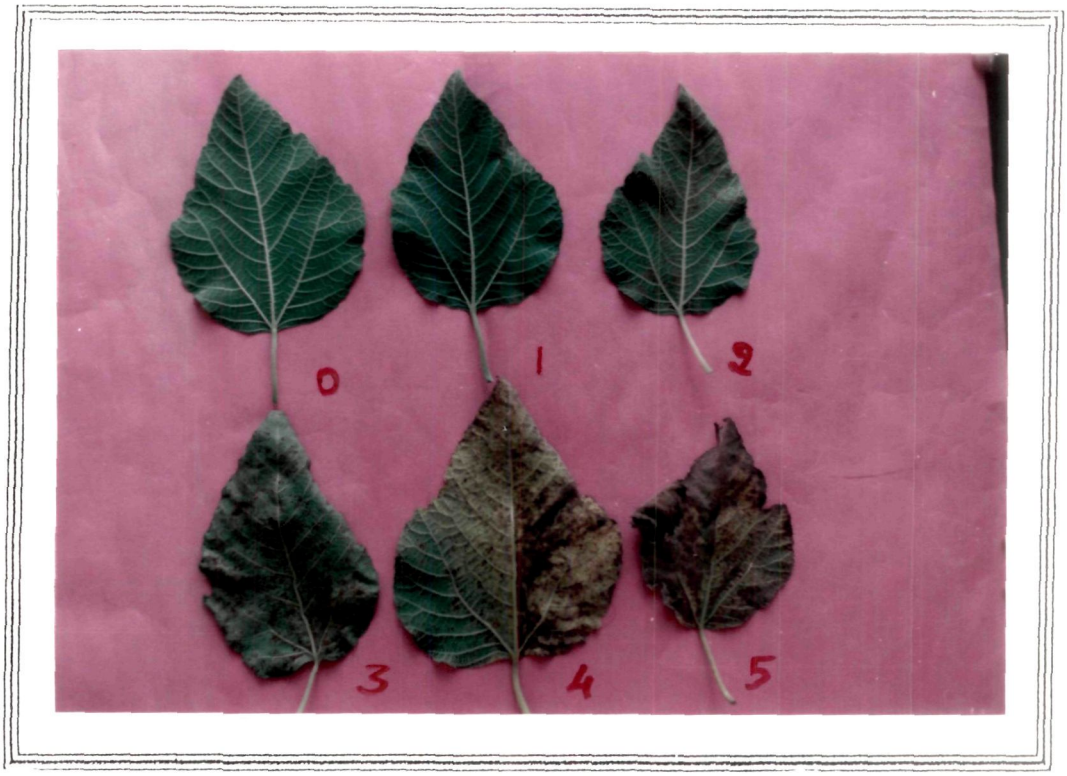

Plate 13. Photograph showing 0 to 5 scale followed for scoring Percent Disease Index.

Plate 14. Photograph showing superiority of Hexaconazole (0.1%) spray in control of fig rust.

interval. In case of supervisory/need based spray a total number of eight sprays were administered. The observations on rust were recorded at 20 days interval. Further, these observations were converted into per cent disease index (PDI) using the formula given by Mc Kinney (1923). The data on PDI of rust are presented in Table 21 .

The result indicated that there was no significant difference among the treatment before spraying fungicide. After the first spray, the maximum per cent disease index was recorded in control (30.00%) and the least was in Hexoconazole at 0.1 per cent (10.66%) and followed by Propiconazole at 0.1 per cent (21.33%), Tridemorph at 0.1 per cent (23.33 %), Chlorothalonil at 0.2 per cent (24.33%) and need based / supervisory spray of Mancozeb at 0.2 per cent (20.00%) which were on par with each other. The disease index was significantly higher in control (90%) over other fungicides, after the 5th spray. The least disease index was recorded in Hexaconazole at 0.1 per cent (31%) followed by Propiconazole at 0.1 per cent (with 41.00 per cent) Tridemorph at 0.1 per cent (42.66%), Chlorothalonil at 0.2 per cent (45.0 PDI) and supervisory / need based spray of Mancozeb at 0.2 per cent (43.00% PDI). However, Triademefon at 0.1 % and Wettable sulphur (0.3%) were least effective with 67.0 and 63.0 PDI respectively .

Table 21. Effect of different fungicides on per cent disease index of fig rust (*C. fici*).

Sl. No	Treatment	Concent-ration(%)	1st observ-ation	2nd obser-vation	3rd obser-vation	4th obser-vation	5th obser-vation	6th obser-vation	7th obser-vation
1	Mancozeb	0.2	4.33*	20.00	35.00	40.00	45.00	47.00	48.00
			(11.66)**	(26.56)	(36.26)	(39.22)	(43.46)	(43.28)	(44.42)
2	Wettable Sulphur	0.3	6.33	25.33	38.00	52.33	56.33	60.00	63.00
			(14.39)	(30.21)	(38.05)	(46.34)	(48.64)	(50.77)	(52.54)
3	Chlorothalonil	0.2	6.66	24.33	36.33	43.00	44.00	45.33	45.00
			(14.58)	(29.54)	(37.1)	(40.94)	(41.54)	(42.71)	(42.13)
4	Tridemorph	0.1	6.00	23.33	32.33	37.00	40.00	42.00	42.66
			(13.97)	(28.87)	(34.24)	(37.26)	(39.23)	(40.39)	(40.59)
5	Propiconazole	0.1	8.33	21.33	30.66	35.0	38.33	40.00	41.00
			(16.68)	(27.49)	(33.62)	(36.26)	(38.25)	(39.23)	(39.62)
6	Hexaconazole	0.1	6.00	10.66	19.33	28.66	30.00	30.66	31.00
			(14.18)	(19.03)	(26.07)	(32.36)	(33.20)	(33.41)	(33.83)
7	Triadimefon	0.1	5.66	20.66	38.00	58.66	64.00	65.33	67.00
			(13.68)	(27.03)	(38.04)	(49.99)	(53.13)	(54.34)	(54.95)
8	Control		7.33	30.00	50.00	73.33	85.66	87.00	90.00
			(15.48)	(33.19)	(45.00)	(58.91)	(67.83)	(68.90)	(71.58)
9	Supervisory Spray of Mancozeb	0.2	5.33	20.00	35.00	38.00	40.00	42.66	43.00
			(12.93)	(26.53)	(36.26)	(38.05)	(39.23)	(40.59)	(40.98)
	S.Em±		1.87	1.97	1.91	2.319	2.267	2.062	2.116
	CD at 5%		NS	5.909	5.725	6.950	6.793	6.180	6.341

* Figures indicate original value

** Figures in the parentheses are angular transformed values

F- Test significant at 5 % level

Plate 15. Photograph showing severity of rust of fig in control (without any fungicide)

Plate 16. Photograph showing efficacy of Propiconazole (0.1%) fungicide identified as second best fungicide.

DISCUSSION

V. DISCUSSION

Fig (*Ficus carica* L.) is an important deciduous fruit crop in tropical and subtropical countries, and is highly delicious fruit known for its medicinal value. It is used in fresh and dried form. The fruit contains proteins. iron, vitamin A and C, high total sugar and various medicinal properties like milk clotting activity, antihelminthic and skin infection. The area under cultivated fig all over the country is presently increasing. Among the important fig growing states in the country, Karnataka is one where it occupies an area of 350 hectares with a production of 3500 tonnes (Anonymous, 1998). However, the production potential of the crop has not been exploited due to several biotic and abiotic factors. The crop suffers from many fungi, bacteria and viral diseases.

The rust caused by *Cerotelium fici* (*Cast.*) Arth. is a number one destructive disease of the fig causing severe defoliation and reduction in yield (Pathak 1980). In the North – Eastern dry zone of Karnataka, it has become an important problem due to its regular occurrence in severe form. However, fig growers find it difficult in getting a good harvest in the absence of a good management practice . Till date, very little work has been done on this particular disease. Hence, the present investigations were undertaken with the following objectives.

1. To under take survey of fig rust in fig growing areas of Raichur, Koppal and Bellary districts.

2. To study the disease development in relation to environmental factors and to explore the possibility of development of prediction model.
3. To understand the pre and post-infectional biochemical changes in the diseased leaf.
4. *In vitro* and *In vivo* evaluation of different fungicides against fig rust.

The results obtained on the above aspects of fig rust are discussed and presented in the pages to follow.

The work was initiated on survey to know the incidence and severity of the disease in three districts of Northern Karnataka viz., Bellary, Koppal and Raichur districts. Survey of the disease over a period of time always gives the intensity with which it affects the yield loss in different locations. In addition, it will be a preliminary source of information on severity of disease in relation to environmental conditions prevailing in different locations and also the impact of pruning and other management practices on the rust severity. The rust of fig was observed during 1999-2000 in and around Raichur, Koppal and Bellary districts. The survey revealed that the disease incidence varied in different locations as well as in different seasons which might be obviously due to difference in varieties grown, timing of pruning, varied management practices followed and environmental conditions prevailing over the localities.

The over all severity generally varied in different areas. The disease was found severe in all districts during September to

November and highest Per cent Disease Index was observed in Devi camp village and Gangavathi in Koppal district followed by Holagundi and Hadagali in Bellary district.

The congenial environmental conditions like cool temperature, high relative humidity and ideal microclimate in the crop canopy must have triggered the disease development in these localities. The least per cent disease index was noticed in Raichur taluk of Raichur district. By and large, the severity of fig rust was more during rainy season followed by winter. A systematic survey made in mulberry rust caused by *C. fici* indicated high incidence of leaf rust in winter followed by rainy season during 1990-1992 (Gunasekahar *et al.*, 1994). However, Philip *et al.* (1997) have observed the prevalence of the disease in rainy season in mulberry rust. The present survey revealed that the incidence is observed both under rainy and winter seasons but severity was high in rainy season due to ideal weather conditions. The future analysis and discussion on influence of weather factors on fig rust development also supports the above statement.

Germination of infectious propagules is an important phenomenon in the life cycle of pathogenic fungi as well as in disease cycle since host penetration and infection entirely depend upon this phenomenon. Besides, abundant and quick germination of infectious propagules play a vital role in faster development and spread of the disease.

In the present investigation, all the congenial conditions were provided for uredospore germination by varying different factors such as incubation period, substrate, temperature and relative humidity. Minimum of 5 hr of incubation period was found essential for initiation of uredospore germination although the per cent germination was only 7.55 and reached the maximum (83.3%) after 24 hrs of incubation period which did not differ significantly with germination (84.20%) at 48 hrs of incubation period. The incubation period of 24 and 48 hrs were found significantly superior over other treatments. Present results are in conformity with the work of Patil (1997) who reported that the maximum *Puccinia helianthi* uredospore germination was noticed after 24 hours (79.80%) of incubation. Hence, 24 hr of incubation period was used in further germination studies. The maximum germination of uredospore was recorded in two per cent sucrose solution after 24 hrs while least in distilled water. The study suggests the requirement of nutrition for germination of uredospores of *C. fici.* The uredospores of different species of rust, required sources of nutrients for their germination, (Naik 1979). The poor germination of uredospores in distilled water is due to lack of nutrients or salt.

Temperature is another most important factor in uredospore germination, infection and further development of the disease. As the maximum germination was obtained in two per cent sucrose

solution, the same was also considered for study on cardinal temperatures. The temperature range of 25-30°C was the most ideal for uredospore germination. However, there was no germination of uredospore at 5°C and a drastic declining trend was observed beyond a temperature of 30°C. Observation made on germination of uredospores of *Puccinia purpurea* on sorghum had (Soumini, 1949) revealed 26 to 29°C as the better temperature condition. Misra and Prasad (1971) got the germination of uredospores of *Puccinia pennisetti* between 8 to 30°C but the best germination was at 20°C with 100% germination. In the present case also, the spores did not germinate at 5°C and 35°C, indicating similar trend in germination. The observations are in conformity with previous findings. Hohan (1978) observed the maximum uredospore germination at a temperature range of 25 to 29°C.

Relative humidity is another important factor for enhancing severity of infection. The present study revealed that, uredospore germination was significantly high at a range of 88-100 per cent indicating most congenial range for uredospore germination. The least uredopsore germination was observed at 66 per cent relative humidity. While, Colhoun (1973) pointed out a relative humidity of over 70 per cent as optimum for mulberry rust development, but Hohan (1978) observed 86-92 per cent RH promoting greater rust intensity in sunflower. The present study on fig rust also showed a similar trend in germination with respect to relative humidity requirements.

Weather plays a pivotal role in the development and spread of the disease. Control measures have to be designed before the disease is observed in the field. Spraying or dusting with fungicides at periodic intervals, besides being costly, also involves the risk of ineffectiveness. Knowledge of weather conditions predisposing the onset and spread of the disease can be used for delineating risky locations and periods for the disease in question and for organising a meteorological disease forecasting services. The experiment was proceeded with monitoring of disease severities on fig variety of Poona at weekly intervals. Weather parameters were collected from the Regional Research Station, Raichur.

When the correlation was worked out between six independent variables (average of previous 7 days) and dependent variable i.e., disease, all six weather parameters indicated a positive correlation. Among them, cumulative rainfall and cumulative rainy days showed highly significant correlation co-efficient of 0.520 and 0.522 respectively. A perusal of data on disease index with weather parameters indicated that during August to October there is a greater increase in disease index and corresponding increase in cumulative rainfall and cumulative rainy days with high relative humidity which have a significant influence on disease development. Hence, observation numbers 1 to 9 were exclusively used for correlation which indicated "r" value of 0.937 for cumulative rain fall and 0.956 for cumulative rainy days. When the variability was worked out

using all the factors on disease incidence an R^2 value of 99.2 per cent was arrived and when the variability was worked out using these two important factors on disease incidence, an R^2 value of 0.878 was obtained with cumulative rainfall alone ($y = a + bx_1$, where a = -6.478, b = 1.704, x_1 = cumulative rainfall) and an R^2 value of 0.914 was attained with cumulative rainy days alone ($y = a + bx_2$ where, a = 7.362, b = 4.55, x_2 = cumulative rainy days) and combined effect of cumulative rainfall and cumulative rainy days contributed for an R^2 value of 0.915 ($y = a + bx_1 + bx_2$ where, a = 4.897, b = 0.256, x_1 = cumulative rainfall, b = 3.90, x_2 = cumulative rainy days). However, cumulative rainy days and rainfall; combined with maximum RH accounted for an R^2 value of 0.918. When the variability was worked out using all the factors on disease incidence, R^2 value of 0.992 was obtained. Thus the best mathematic equation with high fitness were identified among them using the above mentioned formula.

The observation numbers from 16 to 24 which coincide from November to January were used for analysis exclusively. The –ve correlation was seen between disease and minimum and maximum temperature, with r values of -0.624 and –0.508 respectively. However, with maximum and minimum RH the corresponding "r" values were 0.350 and 0.394 respectively, which has to be pondered from the fact that this period from November to January starting from 16th to 25th observation is conspicuously marked by the absence of rainy days and obviously rain fall as well. In the absence of rainfall, the disease

incidence is the result of dew and relative humidity during November to January. The results of the present investigations are in agreement with Hohan (1978), who showed that a day temperature range of 25.5 to 30.5°C with a relative humidity of 86 to 92 per cent promoted greater rust intensity in sunflower during an epidemological studies conducted at Coimbatore. The relative humidity was positively correlated with the incidence of rust. Bulbule *et al.* (1989) pointed out rust of groundnut occurred early during 1988 and 1989 rainy season crops due to cool and warm weather conditions, favourable for infection and disease development. In the post-rainy season crop the rainfall received during the crop growth was low through out and disease severity was high due to prevailing humidity conditions accompanied by favourable sunshine period. The present study on fig rust also showed a similar trend in disease development with respect to weather factor.

Slow rusting cultivars are becoming popular now a days in many crops particularly in field crops. Slow rusting is known as the slow rate of development of rust disease. This type of resistance is preferred since slow rusting varieties allow certain amount of disease development of previously undetected virulent rust strains becoming infective and accordingly may remain so for period of time, longer (Hookar, 1987). There are various mechanisms such as reduction in penetration, infectability, pustule size, pustule development, penetration, spore deposition and increase in latent period which are responsible for the

host resistance that ultimately result in slow rusting. This phenomenon of resistance is horizontal in nature (Van der plank, 1968). Slow rusting varieties are important to minimise the rate of spread of the disease and to check the possible occurrence of epidemics with out causing any adverse effect on the yield. By this, the survival of pathogen is not threatened since exertion of selection pressure is minimised. Hence some of the slow rusting components were studie in fig rust in both the varieties.

Both Poona and Bellary varieties showed a latent period of 8-9 days. The uredia per square centimeter ranged from 4.49–4.73 and 4.32 – 4.52 cm^2 in Poona and Bellary respectively. The uredium of Poona variety measured 0.155 – 0.224 mm^2 where as that of Bellary was 0.178 – 0.215 mm^2 . The uredospore per uredium in case of both Bellary and Poona varieties ranged from 1500–2500 where as the size of uredopsore ranged from 1-1.1 x 1.1 µm in case of Poona and Bellary varieties. Observations on various components of slow rusting indicated no differences among the two genotypes with respect to AUDPC values, latent period, uredia per square centimeter, size of the uredium and uredospore per uredium. None of them could be designated as slow ruster in the absence of resistant check in the present study. Chandramouli (1992) studied that the slow rusting phenomenon and components in cowpea cultivars against rust which indicated that latent period, number of pustules per cm^2, size of the pustule and number of uredospores per pustule were the important components of slow rusting resistance in cowpea

varieties *viz.*, V-16, V-70, TVX-944, V-37 and V-240 having recorded longer latent period, lower number of pustules per cm^2 of leaf area, smaller pustule size and lower number of uredospores per pustule, but the reverse trend was observed in fast rusting varieties, C-152 , HG-171 and in intermediates such as NPRC-1 and 3.

Plant tissues respond to injuries with the production of fungitoxic substances around the site of injury in concentrations high enough to inhibit the growth of most of the fungi that cannot infect the host. These components include mostly phenolics, their oxidation products and also the phytoalexins. One of the major biochemical properties of phenolic components is their antimicrobial activity and it was often assumed that their major role in plants is to act as protective compounds against disease causing agents such as fungi, bacteria and viruses.

The present investigation indicated that total phenolic content was higher in diseased tissues compared to healthy tissues. The increase in phenolic content was 1.44 and 1.33 times more in diseased tissue than healthy in Bellary and Poona varieties respectively. Similar trend was observed in orthodihydroxy phenol content also recording 1.56 and 1.46 times more in diseased tissues compared to healthy in both Bellary and Poona varieties of fig respectively. It is commonly observed in many crop plants higher amount of phenols and ortho–dihyroxy phenols contents are estimated on diseased tissues compared to healthy (Dwivedi, 1990 ; Thompson and Broderick, 1984). However, higher concentrations

of phenolic componds was noticed in diseased leaves compared to healthy leaves of different crop plants by many researchers (Walker and Stahmann, 1955; Klement and Good man, 1967 and Rohringer and Sumborski, 1967; Arora and Wagle, 1985). In case of fig varieties well defined resistance to rust have not been identified so far and in the light of the above fact it is not possible to understand the role of phenols in fig rust resistance.

In the present study, higher amount of total phenol and ortho-dihydroxy phenols in the diseased leaf might be due to the post-infectional effect of *C.fici* on fig which must have triggered their production leading to encountering of higher amounts of phenols and ortho-dihydroxy phenols. Higher amount of phenols were estimated in betel leaf infected with *Colletotrichum gloeosporioides* as compared to healthy leaves (Naik *et al.*, 1988).

In general the infection by some pathogens brings in a lot of changes in respiration and photosynthesis which are very vital processes taking place in plants leading to a wide fluctuations in sugar (Farkar and Kiraly 1962; Klement and Goodman 1967). Total sugar content was more in discased samples as compared to healthy sample in the present host pathogen interaction.

The total sugar was 1.75 and 1.72 times more in the diseased than healthy tissues of Bellary and Poona varieties respectively.

The trend was similar in reducing sugar as well with 1.3 and 1.23 times more in diseased sample compared to healthy samples of Bellary and Poona varieties of fig. Obviously, non reducing sugar component also behaved in a similar fashion with 3.3 times more in diseased sample of Bellary variety and 2.93 times more in diseased sample of Poona variety. Earlier workers *viz.*, Patil and Kulkarni (1977) observed increase in reducing, non reducing and total sugars in rust infected leaves of sunflower as compared to healthy leaves. Besides, Gupta *et al.* (1992) studied the metabolic changes in groundnut leaf due to leaf spot pathogens and found that the levels of total sugar increased after infection in all susceptible and tolerant cultivars. Total sugar content increased in susceptible genotypes of groundnut with the advancement of infection by the leaf spot pathogen (Benagi, 1995). Present findings are in conformity with the results of previous workers. It might be probably due to accumulation of sugar during disruption of normal phloem transport of plant tissue or due to release of amylases in the disorganised host cells owing to invasion by fungus (Okasha *et al., 1968*).

The use of fungicides has become an inevitable option for managing the disease particularly in fig in the absence of any resistant cultivars. Chemical control is an important tool for managing any disease particularly when the disease is already prevalent in the field. Hence, screening of fungitoxicants and new generation molecules were tried both in laboratory and field conditions to know their relative efficacy.

In vitro screening of fungitoxicants provide information regarding their efficacy against the pathogen, and thus serve as a guide for field testing. Among non systemic fungicides, Mancozeb was found to be the most effective with inhibition of uredopsore germination to the extent of 77.37 per cent followed by Chlorothalonil with 71.06% and least with Wettable Sulfur (42.43%). Efficacy of Mancozeb was earlier reported by Patil (1997) on sunflower rust and Rayachaudhari and Verma (1986) on rust of phalsa, Nazeer Ahmed *et al.* (1993) and Desai (1998) on fig rust. Among systemic fungicides, Hexaconazole was significantly superior with 91.27 per cent inhibition which was on par with Propiconazole (89.42%) followed by Tridemorph (79.75%) at 0.1 per cent and the least per cent inhibition of uredopsore germination was obtained in Triadimefon (36.84%) at 0.1 per cent . However, with increase in the concentration of systemic fungicides from 0.025 to 0.1 per cent , there was an increase in the inhibition of spore germination as well. These results are in agreement with Patil (1997) who reported that Hexaconazole, Propiconazole, Tridemorph and Cyproconazole were found to be effective even at lower concentrations (0.025 and 0.05%) unlike Mancozeb at higher concentrations (0.1 and 0.2%) against sunflower rust (*P.helianthi*). Similar results were also obtained by Benagi (1991) who noticed the efficacy of Propiconazole, along with other fungicides such as Tebuconazole. Oxadaxil, Chlorothalonil and Diclobutrazole in inhibiting the uredopsore germination of *P. arachidis*.

Further, systemic and non systemic fungicides were tested on fig rust under field conditions using the best concentration identified under *in vitro*.

The least disease index was recorded in Hexaconazole at 0.1 per cent with 31% followed by Propiconazole at 0.1 per cent with 41%. Tridemorph 0.1 per cent with 42.66% and need based / supervisory spray of Mancozeb at 0.2% with 43 PDI and Chlorothalonil at 0.2 % with 45 PDI. However, Triademefon at 0.1 per cent and Wettable sulphur at 0.3 per cent were least effective with 67.0% and 63% PDI respectively. These results are in agreement with the observations made by Chandramouli *et al.* (1997); Sharma *et al.* (1999) who also showed that fungicides, Hexaconazole and Hexaconazole in combination with Captan at 0.2 per cent were highly effective in control of coffee rust and grape rust respectively. Mancozeb, Tridemorph, Cyproconazole and Propiconazole were effective in controlling fig rust. (Nazeer Ahmed *et al.* 1993, Desai and Jamadhar, 1997 and Desai, 1998).

Future line of work

1) The survey and surveillance of the disease may be extended to other districts of Karnataka and also other states to know the regional and national disease distribution and severity map on the basis of large scale assessment on a continued basis.
2) The rust development on a fig variety under field conditions led to the construction of model using environmental parameters. Since the

present model is based on few data sets, the observation on disease development may be collected from different locations with more number of data sets, on environmental variables in order to make it more meaningful. It is also essential to include dew or leaf wetness as one of the most important environmental factors in developing a better forecasting system for rust. Further there is need for validating the model developed with the actual data of the season.

3) There is need to identify the resistant cultivars against fig rust. This could be used as one of the components and would go a long way in managing the rust.

4) Biochemistry of resistance needs to be properly understood. The studies on enzymes need to carried out for better understanding of the resistance mechanism.

5) It is ideal to work out the schedule on a larger scale along with botanicals/biopesticides and resistance cultivars to develop an integrated disease management (IDM) model for fig rust.

6) Residual toxicity and waiting periods of these chemicals may be studied.

SUMMARY

VI. SUMMARY

Fig (*Ficus carica* L.) is an important deciduous fruit crop in tropical and sub tropical countries and is highly delicious fruit known for its medicinal value. Being potentially a high value fruit crop, for dry land horticulture it is used in fresh and dried form. The rust caused by *Cerotelium fici* is the most important fungal disease reported in India for the first time by Butler (1914) which brought in severe defoliation and yield loss.

The present investigation included survey, epidemiology prediction model, slow rusting components, biochemical studies and *in vitro* and *in vivo* evaluation of fungicides. The results obtained are summarised here under.

Survey carried out during 1999-2000 in Bellary, Koppal and Raichur district of Northern Karnataka revealed that the rust disease was more severe in Koppal district than in Bellary district. Maximum PDI was recorded in Koppal followed by Bellary and Raichur. Koppal district was a hot spot for fig rust disease during 1999-2000. Devicamp village in Koppal district recorded maximum disease severity with 92.5 PDI.

Uredospore germination was maximum after 24 hours of incubation registering 83.3 per cent in two per cent sucrose solution.

The temperature range of 25-30°C and relative humidity of 86-100 percent were the most ideal for maximum uredospore germination.

Role of weather factors on the development of rust of fig caused by *C. fici* was studied. All six weather parameters indicated a positive correlation but among them, cumulative rainfall and cumulative rainy days showed highly significant correlation co-efficient (r) values of 0.520 and 0.522 respectively. A perusal of data on disease index with parameters indicated that during August to October there is a greater increase in disease index and corresponding increase in cumulative rainfall and cumulative rainy days with high relative humidity which have a significant influence on disease development. When the variability was worked out using these two important factors on disease incidence, an R^2 value of 0.878 was obtained with cumulative rainfall alone ($y = a + bx_1$ where, a=-6.478, b=1.704 , x_1= cumulative rainfall)) and R^2 value of 0.914 was attained with cumulative rainy days alone ($y = a + bx_2$ where, a = 7.362, b = 4.55, x_2 = cumulative rainy days) and combined effect of cumulative rainfall and cumulative rainy days contributed for an R^2 value of 0.915 ($y = a + bx_1 + bx_2$ where, a = 4.897, b = 0.256, x_1 = cumulative rainfall, b = 3.90, x_2 = cumulative rainy days). These factors combined with maximum relative humidity accounted for R^2 values of 0.918. When the variability was worked out using all the factors on disease incidence an R^2 value of 0.992 was obtained. Thus, the best mathematic equation with high fitness were identified among the various equations.

An insight on slow rusting components of fig rusts revealed that a latent period of 8-9 days was noticed for both the

varieties with uredia per centimeter square of 4.49 -–4.73 cm^2 for Poona and 4.32 - 4.52 for Bellary. The uredium size ranged from 0.155 -0.224 mm^2 for Poona and 0.178 - 0.215 mm^2 for Bellary. The uredospores per uredium were 1500 – 2500 and the size of uredospore of 1-1.1 x 1-1.1 µm was noticed for both the varieties. The AUDPC values for both the varieties was 9166.01 and 8815.94. Thus both the varieties behaved in a similar fashion to all the components of slow rusting and hence none of them could be designated as slow ruster.

Biochemical studies on healthy Vs diseased indicated that total phenol, ortho-dihydroxy phenol contents were high in diseased sample of Bellary and Poona as compared to healthy samples. Similar trend was noticed in reducing sugar, non reducing sugaıandtotal sugars in both Bellary and Poona varieties

In *vitro* evaluation of fungicides indicated that non systemic fungicides like Mancozeb and Chlorothalonil and systemic fungicides like Hexaconazole, Propiconazole and Tridemorph showed higher inhibitory effect on uredospore germination and the least inhibitory effect on uredospore germination was noticed in Wettable Sulphur and Triadimefon.

In vivo evaluation of non systemic and systemic fungicides indicated that Hexaconazole recorded least disease index followed by Propiconazole, Tridemorph,Chlorothalonil and supervisory or need based spray of Mancozeb.

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APPENDIX

APPENDIX -I

Mean monthly meteorological data during the experimental period (1999–2000) recorded at the meteorological observatory of the Regional Research Station, Raichur.

Months	Rainfall (mm)	No. of Rainy days	Temperature °C		Relative humidity (%)
			Maximum	Minimum	
	1999-2000	1999-2000	1999-2000	1999-2000	1999-2000
June	79.20	9	33.99	22.84	65.23
July	69.60	7	34.11	22.89	64.99
August	238.80	10	32.37	21.60	72.18
September	84.40	8	31.83	22.23	69.88
October	98.60	6	30.26	21.24	71.19
November	0.00	0	32.30	17.70	57.00
December	0.00	0	30.50	15.90	55.80
January	0.00	0	32.40	17.00	49.80
February	0.00	0	33.78	18.78	47.25

EPIDEMIOLOGY AND MANAGEMENT OF FIG RUST
[*Cerotelium fici* (Cast.) Arth.]

SREEKANTAPPA H. **2000**

M. K. NAIK
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ABSTRACT

The survey of the fig rust disease in three districts of Northern Karnataka revealed that the disease was more severe in Koppal than Bellary and was least in Raichur. Koppal district was a hot spot for fig rust disease during 1999-2000.Uredospore germination was maximum after 24 hrs of incubation. The temperature range of 25-30^{0}C and a relative humidity of 86-100 per cent were the most ideal conditions for maximum uredospore germination.There was a greater increase in disease index during August to October, the period with increased cumulative rainfall (r=0.937) with higher number of rainy days (r=0.956) having high relative humidity which have significantly influenced the disease development. A step wise multiple regression analysis indicated an R^2 value of 0.878, 0.914 and0.915 with cumulative rain fall (x_1) , cumulative rainy days (x_2) and combined effect of the two factors respectively. These factors combined with maximum relative humidity accounted for an R^2 values of 0.918. Thus the best mathematic equation with high fitness were identified as

$Y= -6.478+1.704x_1$,$Y=7.362|+4.55x_2$ and $Y=4.897+0.256\ x_1 +3.90x_2$

The two varieties, Bellary and Poona behaved in a similar fashion to all the components of slow rusting *viz* AUDPC, latent period, uredium size, uredospore per uredium, number of uredia per cm^2 and hence none of them could be designated as slow ruster. The total phenol, ortho-dihydroxy phenol, reducing sugar and non-reducing sugar contents were high in diseased sample of Bellary and Poona varieties as compared to healthy samples.In the *in vitro* evaluation of fungicides, mancozeb and chlorothalonil among non-systemic fungicides and Hexaconazole, Propiconazole and Tridemorph among systemic ones were very effective in inhibiting the uredospore germination. In the *in vivo* evaluation, Hexaconazole recorded least (31 %) disease index followed by Propiconazole (41 %), Tridemorph (42.66%), Chlorothalonil (45 %) and need based spray of Mancozeb (43 %). However, Triadimefon and Wettable Sulphur were least effective with 67.00 % and 63 % disease indices, respectively.