PERPETUATION, PHYSIOLOGIC SPECIALIZATION AND MANAGEMENT OF BLACK STEM AND LEAF RUSTS OF WHEAT

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By

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CERTIFICATE

This is to certify that the thesis entitled **"PERPETUATION, PHYSIOLOGIC SPECIALIZATION AND MANAGEMENT OF BLACK STEM AND LEAF RUSTS OF WHEAT"** submitted by **Mr. MOHAMMED KIYAR** for the degree of **MASTER OF SCIENCE (AGRICULTURE) in PLANT PATHOLOGY,** of the 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.

DHARWAD
2nd SEPTEMBER, 2002

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INTRODUCTION

I. INTRODUCTION

Wheat is the most widely grown and consumed food crop of the world cultivated on a larger area and produce more tonnage of food than any other cereals. There had been a steady increase in wheat production in the world. (Rajeev *et al.*, 1998).

Wheat occupies an area of 211.06 m. ha with a production of 566.8 m. tons in the world. India stands second among wheat producing countries both with respect to area and production. Wheat production in India during the 1999-2000 *rabi* season was in the magnitude of 68.50 m. tons. India's average wheat productivity in the recent years being 2.90-3.00 t/ha. (Anon., 2001).

In Karnataka, wheat is grown on an area of 0.248m.ha with a production of 0.190m.tons with the productivity of 766 kg/ha during *rabi* 1998-99 (Anon., 1999). It has already been proved to be the best component crop under multiple cropping system of the state.

Wheat crop is subjected to a number of diseases, which are responsible for reducing overall production to a greater extent, because the plants in all stages of growth and in all natural environments are subjected to various biotic and abiotic stresses that interfere with normal metabolism. Weather, toxicants, pollutants, insects, fungi, bacteria, viruses, nematodes and weeds are primary constraints coming in the way of wheat production. However, the diseases caused by fungi are responsible for taking the heavy toll of the crop in the country and elsewhere in the world.

The most notorious, shifty enemies and prevalent pathogens on wheat are the three rusts, *viz.*, black stem rust (*Puccinia graminis var. tritici* (Pers.) Erikss. and Henn.), leaf rust (*Puccinia recondita* Rob.ex. Desm. *f.sp. tritici*) and yellow rust (*Puccinia striiformis* West), which pose serious threat to the stability of its production.

Historically, wheat rusts have played significant role in the agriculture of early civilization and today, there is a well documented account of their ability to cause epidemics throughout the world.

The rusts are responsible for the considerable damage to the wheat crop. The losses caused due to rusts vary from region to region. Stripe rust or yellow rust is confined to cooler parts of the country comprising of the hilly mountains and foot hills of Himalayas, Nilgiri and Pulney, states of Himachal Pradesh, Punjab, Haryana, Uttar Pradesh and parts of Rajasthan. It is totally absent from south India except in Nilgiri and Pulney hills of Tamil Nadu. Black stem rust though prevalent all over the country, normally appears in epidemic form only in southern, central and eastern parts of India, where normally high temperatures prevail during the crop season. However, leaf rust is an universal problem.

Various loss estimates due to rusts have been published from time to time. Mehta (1941) reported the losses at Rs.60 m. annually and Prasada (1965) estimated the losses of Rs.392 m. in India.

Though, the uredospores and teleutospores of rusts are destroyed in the plains due to prevailing high summer temperatures, the rusts can

survive in the hills in the form of uredospores on the self sown plants, ratoon tillers, off season plants in some areas and on regular *rabi* crops in the hills, particularly in the south (Goel *et al.*, 1995).

Kulkarni (1984) has clearly shown off-season survival of wheat rusts in Chickmagalur and Chitradurga districts of Karnataka. He has also established the role of off-season wheat in the epidemiology of rusts in India.

Fifty years of virulence survey reveals that, wheat rusts population is highly variable and adopted to many unrecognized components in a particular environment. The component of parasite population may be genetically competent; however, their reproductive potential will also be determined by temperature, humidity and other factors (Bahadur, 1986).

Existence of variability in rust pathogens makes it necessary to have an effective system of virulence analysis. It provides an important clue for the management of rust resistant genes by way of their efficient deployment.

The breeding for resistance has been the main approach for management of rusts in India and elsewhere in the world. Different genes for rusts resistance being available among many diverse varieties and those of the virulences being widely dispersed, hence the management of rusts is by no means an easy task.

Wheat rusts are shifty pathogens. Hence, it is necessary to identify the race composition in an area, where the disease exists in order to have

effective management. It is also important to know, how the pathogen/pathogens survive in a given environment. Nowadays, the application of chemical has become a futile exercise to manage wheat rusts, so the best option to manage them is through genetic approaches, i.e. host plant resistance.

The isolation and characterization of specific stem and leaf rust resistance genes have made it possible to determine exactly which resistance genes are present in commercial wheat cultivars and breeding lines. This information is extremely valuable in breeding programme, where maintenance of rust resistance is a top priority (Kolmer, 1996).

These investigations were taken up only on black stem rust and leaf rust because, in Karnataka, these two rusts are prevalent but not yellow rust.

In view of the above facts, the present investigation was undertaken with the following objectives:

1. To study the perpetuation of stem and leaf rust pathogens under different conditions of incubation.,
2. Mass production and maintenance of inocula of stem and leaf rusts.,
3. Identification of physiologic races of stem rust (*Puccinia graminis var. tritici)* and leaf rust *(Puccinia recondita f.sp. tritici)* .,and
4. Management of wheat rusts through host plant resistance and documentation of resistance genes.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Wheat crop in India suffers from several diseases which cause substantial losses in yield as well as grain quality. Out of the various diseases known to attack this crop, the rusts have been regarded as the most dreaded pathogens. All the three rusts *viz.*, the black stem rust (*Puccina graminis var. tritici),* leaf rust (*P. recondita f.sp. tritici*) and stripe rust (*P.striiformis*) are prevalent in India and also elsewhere in the world.

ECONOMIC IMPORTANCE

Although cereal rust diseases are of the major significance historically, estimate of the actual yield losses incurred received attention only in the twentieth century due to a better understanding of the disease biology and an increasing need to justify economically the financial investment in control programme.

Roelfs (1978) compiled an over view of losses due to the cereal rusts in the United States of America from 1918 to 1976, noting state wide yield reduction of 50 per cent or more in the epidemic years due to black stem rust and leaf rust. During the 1960, the black stem rust was conservatively estimated to have reduced wheat yield in North America by over one million tonnes annually. Yield losses due to cereal rusts have also been reported from the Indian sub-continent and Middle east. Severe epidemics have been recorded since the early 1800s in India (Joshi, 1975). In Australia, occurrence of severe black stem rust and leaf rust

epidemics in 1980s resulted in the establishment of State Department of Agriculture in New South Wales and Victoria (Rees and Platz, 1975).

Occurrence of epidemics of three rusts in India has been chronologically provided by Nagarajan and Joshi (1975) and Joshi *et al.*, (1980). Severe rust epidemic occurred in Central Province in 1832 and 1879. The 'Sonalika epidemic' of leaf rust swept over entire Uttar Pradesh and parts of Bihar in 1980(Joshi *et al.*, 1984).

Hasabnis (1998) estimated the yield losses due to stem and leaf rusts to the extent of 60.37 per cent in some of the varieties tested.

PERPETUATION OF WHEAT RUSTS

In many wheat growing countries other than India, several species of *Berberis* play a role as alternate host in the perpetuation of the black stem rust from one season to the next. In contrast to situation elsewhere, alternate hosts play no significant role in the annual recurrence of rusts in the plains of India. Though, the uredospores and teliospores of the rusts are destroyed in the plains by the prevailing high summer temperatures, the rusts can survive in the hills in the form of uredospore inoculum on self-sown plants, ratoon tillers, off-season plants and in some cases on the regular summer crop in the hills, particularly in southern India (Goel, *et al.*, 1995).

Similarly, it has been proved that, *Thalictrum* spp. occurring in the hills is non- functional as far as perpetuation of the leaf rust is concerned. The aceial stage occurring on *Thalictrum javanicum* BL. in

Shimla hills has been connected with brown rust of *Agropyron semicostatum* Boiss (Joshi, 1986).

In the plains of India as well as in the North Himalayan hills, wheat is sown during October –November except in Lahul valley in the Himalayas, where, it is grown as a summer crop during June –October. The crop in the plain is harvested earlier (March-April) than in the hills, where, it is harvested in May-June. The summer temperatures of the plains do not permit the survival of uredospores as well as teliospores. The only possibility, therefore, is that the inoculum survives as uredospore on self sown wheat, ratoon tillers in the regions of Himalayas in the North and the Nilgiri and Pulney hills in the south, where temperature during summer is favourable for survival of rust uredospores (Sharma, 2000).

Role of collateral hosts in the perpetuation of wheat rusts was studied by many workers. Prasada (1951) found the natural occurrence of *Puccinia graminis var. tritici* on many grasses such as *Bromos patulus* Mert and Koch, *B. coloratus* Steud, *B. carinatus* H. & A., *B. mollis* L., *B. japonicus* Thunb, *Hordeum distichum* L., *H. murinum* L., *H. stenostchys* Godr., *Lolium perenne* L., *Hilaria jamessi* (Torr.) Benth, *Aegilops squarrosa* L.and *A. ventricosa* Tausch.

The uredospores surviving and multiplying on collateral hosts (self sown wheat, ratoon tillers) infect the wheat crop first in the hilly tracts and subsequently, the uredospores from this crop are blown to crop in foot hills and finally to plains. In the Nilgiri and Pulney hills of the south,

wheat is cultivated all the year round and the uredial stage has been observed on the plant throughout the summer (Sharma, 2000).

Till recently, it was thus believed that, the primary inoculum for black stem rust comes from the north as well as south. However, it was observed that black stem rust appears in the south much earlier than in the northern India. Hence, the change over of major portion of the inoculum of black rust coming from northern hills is less. Thus, major portion of the inoculum for the plains actually moves from south to the north and that certain regions of central India may serve as reservoir of inoculum from where it spreads to all areas of the main wheat belt in northern parts of India (Joshi, 1986).

Uredospores of all the three rusts retained a fair amount of viability even after a month at 5°C. Black stem rust takes the longest time to appear and yellow rust the shortest. But at high temperature the position is reversed (Mehta, 1950).

An extensive survey was conducted in Karnataka to locate the focus of infection of black stem rust of wheat. It was found that, the farmers grow wheat during off season in the plains of Chikmagalur and Chitradurga districts of Karnataka. The rust inoculum on off season wheat served as secondary focus of infection for further spread. (Kulkarni, 1984).

Eversmeyer and Kramer (1989) measured the effect of temperature, moisture, light intensity and host: parasite interaction on viability and

survival of uredospores of *P. recondita f.sp. tritici* and *P. graminis var. tritici.* Survival of uredospores suspended in the atmosphere was significantly longer during summer conditions compared with winter.

MASS PRODUCTION AND MAINTENANCE OF INOCULA

The success of any programme on breeding for disease resistance depends largely on proper screening of germplasm for resistance against the pathogens. Under Indian conditions, considerable difficulty is experienced in the maintenance of wheat rust cultures in the plains and also in creating artificial epiphytotics in the experimental plots (Joshi *et al.*, 1988).

In India, Joshi (1965) used maleic hydrazide for the multiplication of inoculum against stem and leaf rusts of wheat and also leaf rust of barley (*Puccinia hordei* Otth).

Joshi (1968) demonstrated that, seedlings treated with 0.02 percent maleic hydazide, applied as a soil drench at the rate of 90-100ml at the time of emergence of seedlings can increase sporulation 4-5 times more in the case of both black and brown rusts.

Chief limiting factor under Indian conditions is the paucity of time for raising adequate amount of inoculum coupled with limited glass house space and this has become a serious factor in handling a large population of plants in the field. However, some of these difficulties can be over come by constructing temporary alkathene houses and raising the inoculum of required races, on adult plant of susceptible varieties like

Motia for black stem rust and NP 8214 for brown rust. Not only the handling of adult plants is easier but the amount of inoculum raised in a given alkathene house space is also more (Joshi, 1968).

Gupta and Srivastava (1973) observed that, uredospores of black stem rust and brown rust were dried under vacuum in bulk for 2-3 hours at 0.5-10mm atmosphere and stored for a year at 4°C in a refrigerator, retained more than 80 percent of viability.

IDENTIFICATION OF PHYSIOLOGIC RACES OF RUSTS OF WHEAT

Eriksson (1894) was the first to report the variability within a rust species, which he named *forma speciales*. The *forma speciales* is defined by their ability to attack a particular species or a group of related species but do not differ in the morphology. This is the first level of variability. Stakman, *et al.*, (1944) first reported variation at still finer level. They tested, a number of wheat lines with a number of cultures of stem rust and discovered that there were different physiologic races within wheat stem rust, that were stable but differed in virulence on particular host lines. Similar specialization was discovered in leaf rust by Johnson and Mains (1932) who developed a set of 11 differentials. Three of these were dropped and the remaining eight became accepted internationally. They were *viz.*, Brevit, Carina, Democrat, Hussar, Loros, Malkoff, Mediterranian and Webster.

Mehta (1941) reported six races *viz.*, 15, 21, 24, 40, 42, and 75 from the 586 collection of samples of black stem rust; six races of brown rusts(10,20,63,106,107 and108) from 408 collections.

Rust pathogens are in a dynamic state and within a few years of large-scale cultivation new resistant cultivars may become susceptible. After the wheat stem rust epidemic, which swept the United States in 1953, caused by a new strain of race 15, and it became known that the pathogen (*Puccinia graminis var. tritici*) contained an indefinite number of biotypes (Stakman *et al.*, 1962). These differed in pathogenicity and other physiological characters. Besides their identification on 12 standard international differentials (Stakman and Levine, 1922), additional cultivars were used for further separating them. This led to the conclusion that, it would be difficult to drive an objective system for classifying races of *P. graminis var. tritici* races until adequate genetics knowledge was established (Stakman *et al.*, 1962).

Misra and Sharma (1963) identified a new race of brown rust of wheat from Punjab on variety 'C.217' during 1961-62 crop and he named it as race 'D'.

The gene for gene theory established by Flor in 1942-opened new perspective and it was clear that, the earlier pathogen nomenclature was not on a sound principle. It, therefore, warranted the necessity to change the virulence identification system to meet the current demands (Gaikwad, 1995).

Australians first modified the stem rust virulence identification procedure and simplified the standard set. Various sets were developed using isogenic or non-isogenic lines in Australia, the United States and Canada to identify the wheat rust virulences (Gaikwad, 1995).

Joshi *et al.*, (1970) reported that, races 12 and 77 of *Puccinia recondita* were the most frequent ones from the 80 percent of samples collected. They also found that race 42B of *Puccinia graminis var. tritici* was fairly common.

Nayar *et al.*, (1975) included another variety NI 5439 and identified biotypes of races 12, 77 and 104 of leaf rust of wheat.

Kadam *et al.*, (1975) analyzed the physiologic races during 1971-74 and found that, races *viz.*, 77,162, and 162A of brown rust were predominant in Peninsular India. Race 77 was graduallly on increase throughout the wheat growing areas. Races 162A appeared to be going down since 1971.

Kulkarni (1978) showed the difference in the pathogenicity to the race 77A and 77B on Bijaga red. It was found resistant to race 77A but susceptible to 77B and concluded that, race 77B was a new virulent race on Bijaga red.

Kulkarni (1978) analyzed different samples from Belgaum and Dharwad districts during 1977-1978 and found that, races *viz.*, 12, 77, 77B, 162 and 162A were most common ones.

In India, Nagarajan *et al.*, (1983) developed new differential sets using isogenic lines for all the three rusts with a new system of nomenclature. These sets are being used for wheat rust virulence identification both at IARI-Regional Station, Flowerdale, Shimla and Regional Wheat Rust Station, Mahabaleshwar. After a year of testing the

new sets for leaf rust were finalized. The 0 set consists of universal susceptible, an Indian line resistant to all races- i.e. Watch Dog, and currently cultivated or useful five bred wheats and the two macaroni wheats. Reactions on these sets are not considered in the nomenclature of the pathogen. Instead, it shows the behavior of the presently cultivated lines, meets the requirement of extension worker. The universal susceptible shows whether the test is uniform and the watch dog would identify any new race that may creep in.

Nargund (1989) found that, the leaf rust races *viz.*, 77(45R31), 77A (109 R31) and 77A-1(109 R 23) were the most predominant in Karnataka during *rabi* 1987-88.

Kolmer (1989) detected 28 virulence combination of *Puccinia recondita f,sp. tritici* in 1989 in Canada using 15 isogenic Thatcher back cross lines as differentials. Virulences of leaf rust pathogen were not detected to resistance genes *viz.*, Lr16, Lr19, Lr21, Lr25 and Lr29.

Nayar *et al.*, (1996) reported that, from the 4606 samples of brown rust of wheat which were analyzed, pathotype 77A-1(109R23) was predominant during 1990-91 and pathotype 77-2(109R31-1) virulent on Lr23 was most frequent in 1992-94.

Hasabnis (1998) surveyed different districts in Karnataka and Maharashtra states during 1996-97 and 1997-98 for virulence monitoring. He reported that, pathotypes from group 77 were widely distributed in surveyed areas.

Isolates of *Puccinia recondita* were obtained from wheat leaf collections made by co-operators throughout the United States and from surveys of wheat fields and nurseries in the Great plain, Ohio valley and Gulf coast states in 1996, 1997and 1998. It was found that, 31 phenotypes among 277 single uredial isolates in 1996, 56 phenotypes among 989 isolates in 1997 and 43 phenotypes among 989 isolates in 1998 (Long, 2000).

DIVERSITY OF RESISTANCE: HOST PLANT RESISTANCE

Screening of wheat varieties for resistance to stem and leaf rusts

Gokhale and Patel (1952) showed relative susceptibility of nine improved wheat varieties to stem rust, as measured mainly by the loss in grain weight. Varieties under test were highly susceptible to all or many of these races at the seedling stage.

Of the 290 varieties and strains tested against 14 races of *Puccinia graminis var. tritici* and 11 of *P. recondita f.sp.tritici* only 'K101' proved moderately resistant to the latter, while the rest were susceptible to both the rusts (Singh *et al.*, 1969).

Mishra *et al.*, (1970) inoculated brown rust on wheat varieties which resulted in the reduction in average plant height, grain weight, volume and yield in susceptible varieties. Two varieties "Lerma rojo" and "E871" were resistant and recommended for use in hybridization programme.

Naik *et al.*, (1974) evaluated varieties for tolerance to leaf rust. Simple linear regression analysis was used to relate grain weight and yield per plant to disease coefficient. They concluded that, there was a direct relationship between yield and leaf rust except varieties *viz.*,Motia, HD4530, EK69, J-1-7, NP200, HP961, Hira and K68 and therefore, these varieties were rated as tolerant.

Nayar *et al.*, (1975) in 1973 -74 isolated a new biotype of race 77 of leaf rust from Dharwad (Karnataka) on wheat variety 'CC 62' and designated as 77A. It produced infection type '4' on wheat variety 'NI 5439' being resistant to type race 77. The varieties *viz.*, HD1739', 'HD1928', 'H1999', 'HD4502', 'HD4503', 'HI7484', 'HI7620', 'Raj911', 'WLI002', 'HS38', 'VL417', 'NS97914', 'N5749', 'IWP 500', 'IWP 503', 'HW 153', 'MP 112', 'MPO 193', 'Anzas', Burges-2', 'Gaza' and 'Yama' were found as resistant donors against race 77 and biotype 77A.

During the year 1976-77, the infection of stem rust was noticed in Dharwad. The infected samples of Bijaga yellow were collected and analyzed for stem rust races and it was found that Bijaga yellow was affected by new virulence 117-A-1. This biotype was observed during 1976-77,1977-78,1978-79 in Karnataka on most of the promising cultivars *viz.*, HI-385,Local red, Bijaga yellow,CPAN-1715,HUW-12,HD-94,A-206,DWR-654,HUW-91 and DWR633 (Kulkarni,1979).

Gundappa (1983) screened 141 wheat varieties against stem rust of wheat. Varieties *viz.*, HD-2009, HD-2320, HD-2329, P-2132, RAJ2232, HD1102, HP1209, HP1487, BW71, BW75, BW78, DL1778, HD2189,

HD2323, HW919, HW888, HW-741, HW-504, HD-2327 remained free from infection. Terminal severity 60S was recorded on Kalyansona and N-59 and 40S in K-8028, K-8027, K-8026, NI-5439 and APAU-1577.

Navi (1986) screened 55 varieties against leaf rust of wheat and out of these HD2428, PBW175, HUW269, NDW374, DL254-2, HS207, VL639, DL230-7, HD2402, DL230-6 and HI1156 have shown immune reaction whereas, remaining144 varieties showed different levels of infection.

Nargund (1989) reported that the severity of leaf rust was more under artificial epiphytotic conditions at Dharwad as compared to natural conditions at Ugar Khurd. Maximum severity of leaf rust (100S) was observed under natural conditions at Ugar Khurd.

Reaction of isogenic lines to black stem rust and leaf rust

Reddy(1974) reported that out of 23 Lr genes that were tested to leaf rust in India, only 10 genes viz.,Lr9, Lr19, Lr15, Lr3(do), Lr3(ka), Lr10, Lr16, Lr1, Lr17, and Lr20 were found to be important in order. In several parts of the world, it is noticed that, Lr9 and Lr19 as completely resistance sources in the seedling stage against leaf rust isolates collected during respective years (Ungar, 1976; Tsikaridze, 1978; Gospodinova, 1987 and Stoyanov, 1982).

Sawhney *et al.,* (1977) tested 14 Lr isogenic lines and reported, Lr9 and Lr19 as resistant sources in seedling stage against 14 individual races of leaf rust under glass house conditions. Lr24 was found to be susceptible to only three races viz., 12, 17 and 20.

Kulkarni (1979) observed that, Sr26 and Sr27, Lr9 and Lr19 isogenic lines remained free from infection of black stem and brown rusts respectively throughout the season at Dharwad, whereas, most of the commercially grown varieties showed infection.

Kulkarni (1980) screened the performance of Sr26 and Sr27 genotypes within the existing races and he observed that, these isogenic lines were free from infection.

Saadovi (1985) tested 24 genes for the leaf rust resistance in Morocco under natural epiphytotic conditions, at three locations. The best resistant genes were *viz*; Lr9, Lr19 and Lr24 followed by Lr3 (Ka), 18, 13, 14a, 20 and 29.

A recent pathogenicity survey of the stem rust in Pakistan revealed that, near isogenic line *viz.,* Sr26, Sr27 and SrGt are resistant to all the isolates of the pathogen, while only one isolate could attack Sr24. Wheat lines with genes *viz;* Sr-5, Sr-9e, Sr-10, Sr11, Sr22, Sr26, Sr27, Sr29, SrTt2, SrGt are resistant to the large number of isolates and provided the best protection against stem rust (Bhatti *and* Ilyas, 1986).

Sawhney and Goel (1986) reported that, near isogenic lines and cultivar of wheat with single leaf rust resistance genes *viz.*; Lr2a, Lr19, Lr21, Lr22, Lr23, Lr24 (Agent), Lr25 (Trasec), Lr26 (Benno), Lr27 (Thatcher) were also resistant to Indian stem rust races. Further, they discussed the presence of Sr genes in combination with Lr isogenic lines.

Kulshresta (1986) reported that most of the Sr genes found to be ineffective individually against Indian races of stem rust in the field and

Sr9b gave certain degree of resistance both at Delhi and Wellington. Sr 11 being extensively used in the Indian breeding programme was found to be susceptible.

Casulli and Siniscalco (1987) reported isogenic lines *viz.*, Lr9, Lr12, Lr13, Lr15, Lr19, Lr19, Lr24 and Lr25 as most effective genes in the field testing at adult plant stage and genes Lr9, Lr19, Lr20, and Lr24 and Lr25 were effective against all the isolates at seedling stage.

Nargund (1989) observed the performance of isogenic lines to leaf rust and reported that, Lr9 and Lr19 remained immune, while Lr3ka, Lr13 and Lr28 showed additional immune reaction during the next season .

Saini *et al.*, (1993) concluded that, Lr1, Lr10, Lr13, Lr14a, Lr17, Lr23 and Lr26 were not useful singly or in combination against leaf rust pathotypes 77A, 77-1 and 77-2, whereas, Lr3, Lr16 and Lr34 conferred resistance.

Hasabnis (1998) showed effectiveness of Lr9, Lr19 and Lr24 against the pathotypes tested and the least effective genes were Lr2c and Lr14a.

Postulation and documentation of genes

Nagarajan *et al.*, (1984) catalogued the avirulence/ virulence genes present in the pathogen cultures causing stem, leaf and stripe rusts and identified the various resistance genes by selecting the appropriate pathotypes by matching technique in a large number of wheat genotypes.

Nayar *et al.*, (1988) postulated Lr genes in two bread wheat cultivars *viz*; HUW 12 and WH322. A comparison of differential seedling reaction of the cultivar to various races of *P. recondita* with those of Lr isolines indicated that, HUW12 carries Lr14a and WH322 carries Lr10 and other unidentified genes.

The reaction of 36 Chinese cultivars following the inoculation with 23 isolates of *Puccinia graminis* indicated that, only resistance genes viz; Sr5, Sr6, Sr8a, Sr11, Sr17, Sr36, Sr tmp were present (Hu, 1988).

Bharadwaj *et al.*, (1989) reported the occurrence of virulence 117-1(166G2) of wheat stem rust and it was mainly recorded from Karnataka and Madhya Pradesh. This virulence could overcome the resistance of many cultivars and Sr37.

Nayar *et al.*, (1993) showed occurrence of gene Lr23 in more than 30 percent of Lr lines. Some of the released varieties having Lr23+ are Bijaga Yellow, DWR39, HD2278, HD2380 and HD2501. Sharma and Saini (1993) explained diversity for resistance to seven pathotypes of *P. recondita* in 88 strains of *Triticum aestivm* L. using infection type and matching technique. The genes identified were *viz*; Lr1, Lr3 and Lr10 in 38.6, 31.84, and 14.7 percent of wheat lines respectively. Only 28.40 per cent wheat lines were expected to carry the genes Lr26. Bahadur *et al* ., (1995) analyzed 28 improved wheat lines and identified genes as Lr1, Lr3, Lr10, Lr19, Lr23, Lr24 and Lr26 alone or in combinations. The observed combinations were Lr1+Lr23 (in 3lines), Lr10+Lr23 (3) and Lr10+Lr26 (3).

Bahadur *et al.*, (1995) analyzed 28 improved wheat lines developed by Indian Agricultural Research Institute, New Delhi for identification of leaf rust resistance genes *viz*; Lr1, Lr3, Lr10, Lr19, Lr24 and Lr26 alone or in various combinations. Genes *viz.*, Lr1 and Lr23 were identified in DW616, DW829,Lr3 in DW 832 and DW833, Lr10-Lr23 in DW774, DW809, DW847; Lr19 in DW 837,DW 838,CP172, CP173, CP175 and CP176:Lr10-Lr23 in DW839, DW840 and DW842: Lr23+in DW722, DW777, DW849 and DW 850.

Gene postulation applies the principle of gene for gene specificity to hypothesize which Lr genes may be present in host genotypes. This method uses the avirulent isolate/resistant host combination from the quadratic check as the definitive combination. Low or incompatible infection types are expressed only when hosts with specific resistance genes are challenged with a pathogen isolates that is avirulent to that gene. All others combinations result in high or compatible infection types. Using this as a basis, it is possible to hypothesize which resistance genes are present by testing the materials with a diverse collection of isolates of *Puccinca recondita* (Kolmer, 1996).

Malker and Singh (1996) postulated resistance genes for leaf rust in 52 selected Bangladesh bread wheat genotypes at CIMMYT, Mexico. Based on multipathotypes reaction on seedling, 10 different Lr genes, either singly or in combination, were detected in those genotypes. The gene Lr13 occurred with the highest frequency (in 34lines) followed by Lr23, Lr10, Lr3, Lr26, Lr16, Lr1, Lr21 and Lr27+Lr31. A combination of

Lr13 and Lr23 was hypothesized to be present in 24 genotypes including the cultivar Kanchan and Protivia. Genes Lr10 and Lr13 were detected in varieties Aghrani and Akhbar. The cultivar Swagat was postulated to carry Lr26 in addition to Lr10 and Lr13. The presence of Lr1 and Lr13 was observed in the cultivar Anand.

Hasabnis and Kulkarni (2001) worked out postulation and documentation of genes for resistance to leaf rust. The infection types displayed by the tester Lr line and commercially grown wheat varieties when inoculated with ten pathoypes *of P. recondita f.sp. tritici* have been listed. The gene Lr 24 displayed consistently low infection types with all the pathotypes. Variety N 59 did not appear to carry any known or unknown Lr genes. A gene of MACS-2846, NI- 146, and NIAW -129and PBN -142 appeared to carry Lr23, Lr26, Lr13, and Lr10, respectively with the additional unknown gene. The Lr24 was postulated from DWR 185 andMACS-284. Adult plant resistance gene, Lr34 was detected in HD -2189, HD-2501 and NIAW -34 in addition to other genes. But, HD-2380 possessed known gene combination (Lr10+Lr23+Lr26).

Singh *et al.*, (1999) evaluated 102 wheat cultivars from China and a set of testers, carrying named Lr genes for resistance at seedling stage against leaf rust races. Variation in seedling infection types of cultivars was compared with that of the testers and genes conferring low infection types were postulated. Over all, nine named genes *viz.*, Lr1(in13cultivars) ,Lr3(12), Lr3bg(2), Lr10(1), Lr13(4), Lr16(49), Lr23(9) and Lr26(81) were identified.

Mahoto *et al.*, (2001) analyzed 43 bread wheat varieties from Nepal against fifteen pathotypes of *P. recondita f.sp. tritici* prevalent to South East Asia. Probable leaf rust resistance genes in these lines were postulated. Genes *viz.*, Lr1, Lr3, Lr9, Lr10, Lr13, Lr23 and Lr26 were identified either singly or in combination in the bread wheat lines. Since Central Nepal also serves as the source for the recurrence of leaf rust for the Indo Gangetic plain, use of wheat varieties with diverse resistance would reduce the leaf rust severity and minimize crop losses.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation was carried out during *rabi* 2000-2001 and 2001-2002 at Department of Plant Pathology, Dr. Sanjay Rajaram wheat Laboratory, Main Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India; Regional Wheat Rust Research Station, Mahatma Phule Agricultural University, Mahabaleshwar, Maharashtra and at Research and Development farm of Ugar Sugar works, Pvt. Ltd, Ugar Khurd, Karnataka. Dharwad is situated in the northern transitional tract of Karnataka at 15° 26' N latitude and 75°07' E longitude at an altitude of 678 m. above m.s.l. Mahabaleshwar is situated in the state of Maharashtra at 17°56' N latitude and 73 °40' E longitude at an altitude of 1382 m above m.s.l. Ugar Khurd is situated in the state of Karnataka at 16° N latitude and 74° E longitude at an altitude of 555.50 m. above m.s.l. The details of the materials used and the methodology adopted during the course of this investigation are given here under.

PERPETUATION OF BLACK STEM RUST AND LEAF RUST

This work was carried out in the Department of Plant Pathology, University of Agricultural Sciences, Dharwad. Fresh uredospore pustules of black stem rust and leaf rust were collected from wheat field of UAS, Dharwad. The samples were well air dried and kept at different conditions of incubation *viz.*, deep freezer, refrigerator, glass house and room temperature. The samples were taken for the study once in fifteen days. Uredospore pustules were taken from each treatment and ruptured

in two per cent glucose solution for germination. Uredospore suspension of both black stem and leaf rusts was placed on clean slides and placed in moist Petri dishes. The Petri-dishes were incubated at room temperature (27±1°c) for 24h. The germination percentage was worked out by counting 100 uredospores under low power objective of the microscope. This work was continued till the uredospores lost their viability.

MASS PRODUCTION AND MAINTENANCE OF INOCULA OF RUSTS

This work was done at Regional Wheat Rust Research Station, Mahabaleshwar both in the glasshouse and in the field for black stem rust and leaf rust of wheat.

Primary level of multiplication of inocula

This work was carried out in the glass house. Seeds were sown in pots for multiplication of both stem and leaf rusts inocula. The varieties used were *viz.*,

A. Pusa 4 for black stem rust.

B. Agra local for leaf rust

Both the varieties used were universally susceptible to all the races. Maleic hydrazide (0.02%) at the rate of 90-140ml per pot was applied. The seedlings were inoculated by brushing with uredospores on the primary leaves. Observations were made after two weeks. When the uredospores were matured, it was taken and inoculated in other pots for

maintenance in the glass house then the pots were taken to the field for further multiplication in the field.

Secondary level of multiplication

This was done in the field in the nursery. All the matured uredospores from the pots were sprayed at boot stage of the varieties. In this case also susceptible varieties were used *viz.*, Agra local, Gulab, Pusa 4, Lal Bahadur, Vijay and Motia. The observations were taken place in two stages (stem elongation and dough) of the crop. When the crop matured the uredospore was taken and inoculated in secondary nursery for maintenance of the inocula.

Secondary nursery inoculum

This was done when the matured uredospores used for inoculation were exhausted. Inocula were taken from secondary level of multiplication and sprayed during the evening hours when the crop was at boot leaf stage. In this multiplication, iron frame was used for convenience. After inoculation, the crop was covered with white muslein cloth and water was sprayed on it to create maximum humidity then covered with tarpalein cloth for 24 h. Observation was made after one week. When the uredospore was matured it was taken and maintained in the deep freezer for further usage.

IDENTIFICATION OF PHYSIOLOGIC RACES OF BLACK STEM RUST AND LEAF RUST

The black stem and leaf rusts samples were collected from wheat field of UAS, Dharwad during *rabi* 2000-2001 and also from farmers' field

during *rabi* 2001-2002, from Belgaum and Dharwad districts. Such samples were taken to Mahabaleshwar and inoculated on universal susceptible variety Pusa 4(for black stem rust) and Agra local (for leaf rust) in order to multiply large quantity of inoculum. Seedlings were raised in the glass house under spore proof conditions. While sowing, the endospermic end of the seeds kept downward for quick and uniform germination. Prior to inoculation, the seven day old seedlings were sprayed with water and the leaves were rubbed with moistened finger to remove the thin layer of cuticular wax. The inoculum in the form of uredospore dust was inoculated by dusting with finger technique on the new set of differentials having Sr and Lr isogenic lines. (Nagarajan *et al.*, 1983).

The composition of differentials of O, A and B sets are as follows:

Black Stem rust

O set	A set	B set
Agra local	Sr 13	Marquis(Sr7+?)
WL711	Sr 9b	Einkorn(Sr21)
Sonalika	Sr11	Kota (Sr28+?)
Lok-1	Sr28	Reliance (Sr +?)
Sr24	Sr8	Charter (Sr11+)
Bijaga yellow	Sr9e	Khapli(Sr7a,Sr13,Sr14)
NI 5439	Sr30	
Nilgiri barley local	Sr37	

Leaf rust

O set	A set	B-set
IWP 94	Lr 14a	Lr2c (Loros)
Karchia mutant	Lr24	Lr2a(Webster)
Raj 3765	Lr18	Lr3a(democrat)
PBW 343	Lr13	Lr20(Thew)
UP 2338	Lr15	Lr1(Malkof)
K 8804	Lr17	Lr26(Benno)
Raj 1555	Lr10	
HD 2189	Lr19	
Agra local		

Maximum care was taken not to contaminate the seedlings with other isolate by washing hands with 0.1 % $HgCl_2$ in every inoculation. Such inoculated seedlings were placed in humidified chamber over night to ensure maximum infection. The plants were then transferred to a green house bench. The reactions were recorded for naming of the pathotypes by following the procedure given by Habgood (1970).After the development of rust pustules, reaction on these sets are grouped either as R or S. Pustules from 0-2 types are taken as resistant(R) and 3-4 and X as susceptible (S). These reactions are further coded to the following binary notation.

Pustule size	**Reaction**	**Binary number**
0	R	0
0;	R	0
1	R	0
2	R	0
3	S	1
4	S	1
x	S	1

Using binary number and decanary value the nomenclature of a virulence was given. The decanary procedure follows raising a number to the base 2 and total of two numbers can be identical. Hence, asset which consists of entries would have a decanary from 2^0-2^7 and decoded value from 1-128.

DIVERSITY OF RESISTANCE

Performance of commercial wheat varieties to black stem rust and leaf rust

Twenty two wheat varieties received from All India Coordinated Wheat Improvement Project, Dharwad were observed for their performance against stem and leaf rusts under natural conditions at Ugar Khurd during *rabi* 2001-2002. Similar trial was conducted in Mahabaleshwar during *rabi* 2001-2002, where twenty two commercially grown varieties were tested for their performance to stem and leaf rust under natural conditions. Terminal disease severity of leaf and stem rusts was recorded at two stages of crop growth i.e., stem elongation and grain filling and the average was taken. Later, 1000 grain weight was also recorded for the trial conducted at Ugar Khurd. The scale proposed by Loegering (1959) including the response values are given as below.

The response was recorded by using the following scale.

0 - Immune. No visible infection on plants.
0; - Nearly immune. Yellow flecks on plants
R - Resistant. Necrotic areas, with or without minute uredia.
MR- Moderately resistant, Small uredia surrounded by necrotic areas.

X - Mesothetic/ Heterogeneous. Variable sized uredia, some with necrosis or chlorosis.

MS – Moderately susceptible. Medium uredia with no necrosis but possibly some distinct chlorosis.

S- Susceptible. Large uredia with no necrosis but possibly some distinct chlorosis.

To combine both the intensity of infection and type of reaction, disease coefficient was calculated by multiplying the per cent infection by response value as given by Loegering (1959).

Reaction type	Response value
O	0.0
R	0.2
MR	0.4
X	0.6
MS	0.8
S	1.0

The Average coefficient of infection is calculated by taking the average of the two observations. Pearson's moment correlation was used for this study to compare the degree of the relationship between independent variable (Disease) and the dependent variable (Yield).

Reaction of Sr and Lr lines to black stem and leaf rusts

Isogenic lines received from All India Coordinated Wheat Improvement Project, New Delhi were screened under artificial epiphytotic conditions,

against mixture of stem and leaf rust races at Regional Wheat Rust Research Station, Mahabaleshwar, Maharashtra. Forty three Sr lines and thirty Lr lines were tested against rusts during *rabi* 2001-2002.

Each isogenic line was sown in a single row of 1.5m length and after every 20 lines susceptible check was sown as infector row. The borders were also covered with susceptible variety Pusa 4 for black stem rust and Agra local for leaf rust in order to create continuous supply of inocula to Sr and Lr lines. The mixture of stem and leaf rusts uredospore inocula to respective lines were inoculated during the evening hours by spraying.

Inoculation of rust races was carried in order to create maximum disease pressure. Terminal disease severity was recorded as per the scale given by Loegering (1959) and combining severity and response value were noted as explained earlier.

Postulation and documentation of genes for resistance

This work was carried out at Regional Wheat Rust Research Station, Mahabaleshwar during *rabi* 2001-2002. The varieties were supplied by Wheat Research Scheme, UAS, Dharwad. For growing seedlings, bread pans were used which can accommodate ten hills per row. A seventh hill of each row was dibbled with seeds of universal susceptible varieties i.e. Pusa 4 for stem rust and Agra local for leaf rust, so as to, compare and confirm higher infection types.

The varieties used were:

1. DWR 225
2. DWR 1006
3. DWR 2006
4. DDK 1001
5. DDK 1009
6. DDK 1019
7. DDK 1020
8. NP 200

The host material included one variety of bread wheat, two durum wheat and five dicoccum wheat and a set of testers having known Sr and Lr genes for postulation of Sr and Lr genes. Twelve pathotypes of *Puccinia graminis var. tritici* and thirteen pathotypes for *Puccinia recondita f.sp. tritici* were used.

A mixture of sandy loam and farm yard manure (FYM) in the ratio of 2:1 was used for growing the seedlings. The mixture was sieved and all the bigger lumps and other extraneous materials were removed. The well friable soil was placed in pots/trays for sowing the seeds.

Seedlings were raised in separate glass house under spore proof conditions. Seven day old seedlings at one leaf stage were inoculated by applying uredospores of respective pathotypes with the help of arrow headed needle. The inoculated pots/trays were sprayed with water to have thin film of water over leaf surfaces. The trays were placed

in humid chamber for 18-20 h, and subsequently they were transferred to glass house. Infection types were recorded on 12th day after inoculation according to system proposed by Johnson and Mains (1932). The postulation of stem rust and leaf rust resistance genes was done by comparing the observed spectrum of low and high infection types of the entries to the respective pathotypes with the infection types of the Sr and Lr lines. Whenever, two or more resistance genes were postulated, it was presumed that, their effect was additive. Compatible infection types were the basis for the presence of the gene in a particular cultivar/ variety.

Statistical analysis of data and interpretation of results

The statistical methods used for some of the studies were correlation coefficient and simple regression analysis, wherever necessary. The results are presented in tabular form, figures and photographs.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Black stem rust of wheat is caused by *Puccinia graminis var. tritici*.. The symptoms are marked by an eruption of elongated, brown pustules on the stalk, leaf sheath, leaves and the stalk being often severely affected. The pustules (uredia) may be about 6mm or more in length and frequently run into one another. They burst early, exposing a brown powder (consisting of uredospores) and surrounded by prominent epidermal fringes. Telia develop later in the same sorus as uredia or independently. They are darker in colour than the uredia and burst through the epidermis in the same manner as uredia, exposing a black bed of spores. The uredospores of stem rust are reddish brown, oval to elliptical, echinulate and single .cells measuring 15-24 µm x 21-40µm. Teliospores are dark brown to black, two celled and elliptical to clavate in shape with tapered apical cell and measure 15-20µm x 40-60µm. They retain a portion of the pedicel or stalk (plate 1a, b, c and d).

The leaf rust caused by *Puccinia recondita* f.sp. *tritici* Rob. ex. Desm. is restricted to wheat and certain grasses and is the earliest rust to appear on wheat in India. The symptoms are observed as the uredia develop on leaves, being rare on the sheath and the stalk. They burst on the upper surface as point of bright orange colour. They are never in rows but may be gathered in small clusters or may be irregularly scattered all over the lamina surface. They are bigger in size than the uredia of yellow rust fungus. The telial pustules are small, oval or linear, dull black and covered by the epidermis. Microscopically, the uredospores of leaf rust are

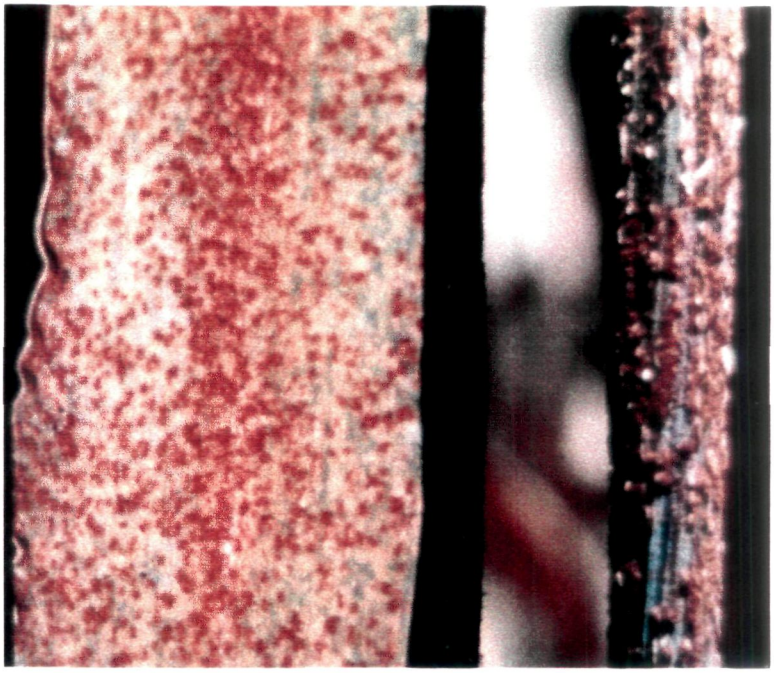

Plate 1a: Photograph showing symptoms (Uredial stage) of stem rust.

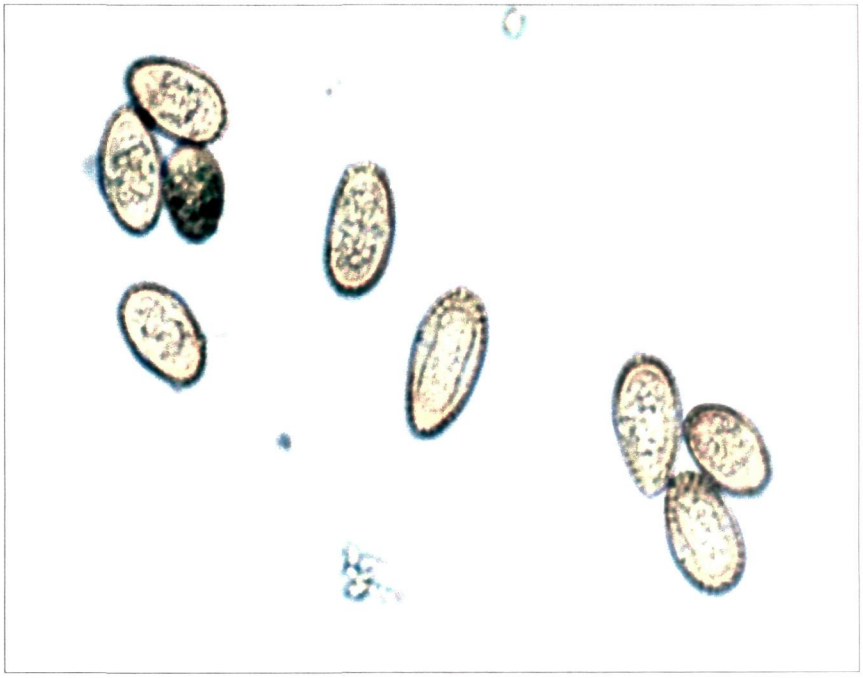

Plate 1b: Uredospores of stem rust of wheat caused by *Puccinia graminis* var.*tritici.*

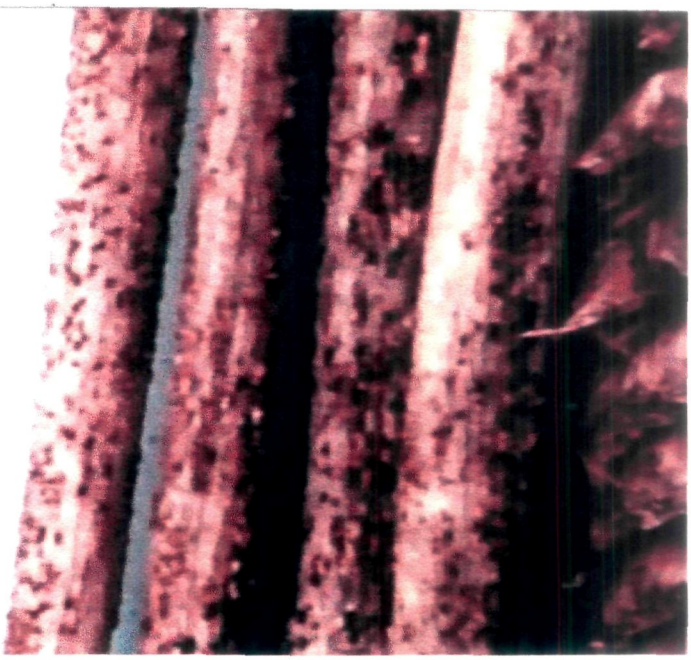

Plate 1c: Photograph showing telial stage of stem rust.

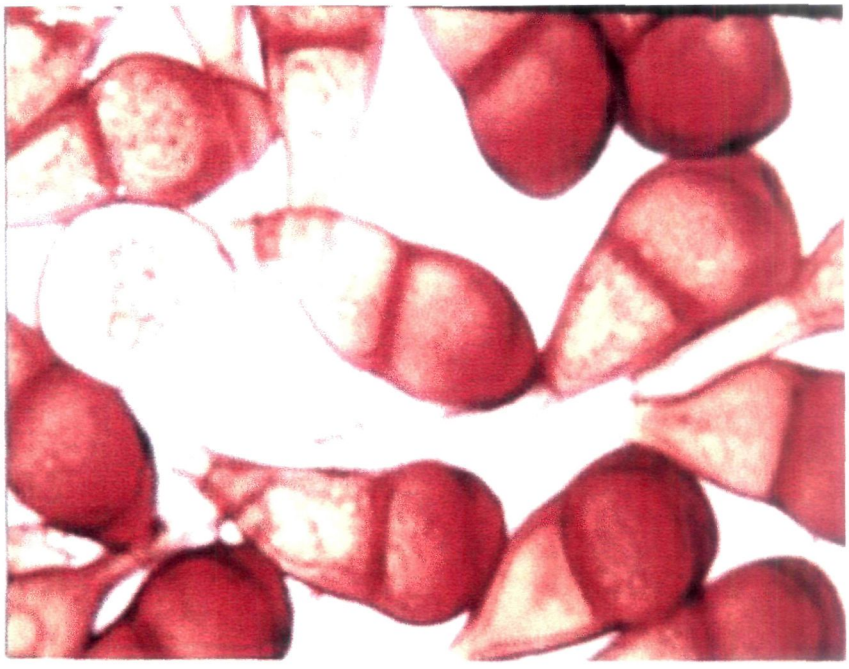

Plate 1d: Teliospores of stem rust of wheat.

spherical in shape, bright orange to red in colour and the wall is brownish and usually measure 15-30µm in diameter. The teliospores are dark brown to black, two celled, thick walled and have a flattened to round crown cap (plate 2a, b, c and d).

PERPETUATION OF BLACK STEM AND LEAF RUSTS

The black stem rust and leaf rust affected samples were collected from wheat field of University of Agricultural Sciences, Dharwad. Such samples were used for survival studies at different conditions of incubation as given in 'Material and Methods'.

The per cent germination of uredospore of black stem rust (*P. graminis var. tritici)* was high in deep freezer (70%) followed by refrigerator (50%). The average percent germination of uredospores for a period of three months was very low in green house (8%) and room temperature (11%) as indicated in table 1.The germination of uredospore for black stem rust was very high in the first 15 days as indicated in the fig. 1 and 2, later they failed to germinate.

The uredospores of stem rust survived for a longer period (90days) in deep freezer followed by refrigerator (75 days). It was found that, low survival periods were recorded from green house (15 days) and room temperature (15 days) as shown in table 1 and fig.1,there after, they lost the viability.

The average uredospore germination of leaf rust for a longer period (90 days) showed the highest percentage from deep freezer (63%) followed

Table:-1 Survival period of uredospores of *Puccinia graminis* var. *tritici* at different conditions of incubation.

Treatments	Per cent uredospore germination	Survival Period (days)
Deep freezer(-5°c)	70	90
Refrigerator(5°c)	50	75
Green house(32± 1°c)	8	15
Room temperature(27±1°C)	11	15

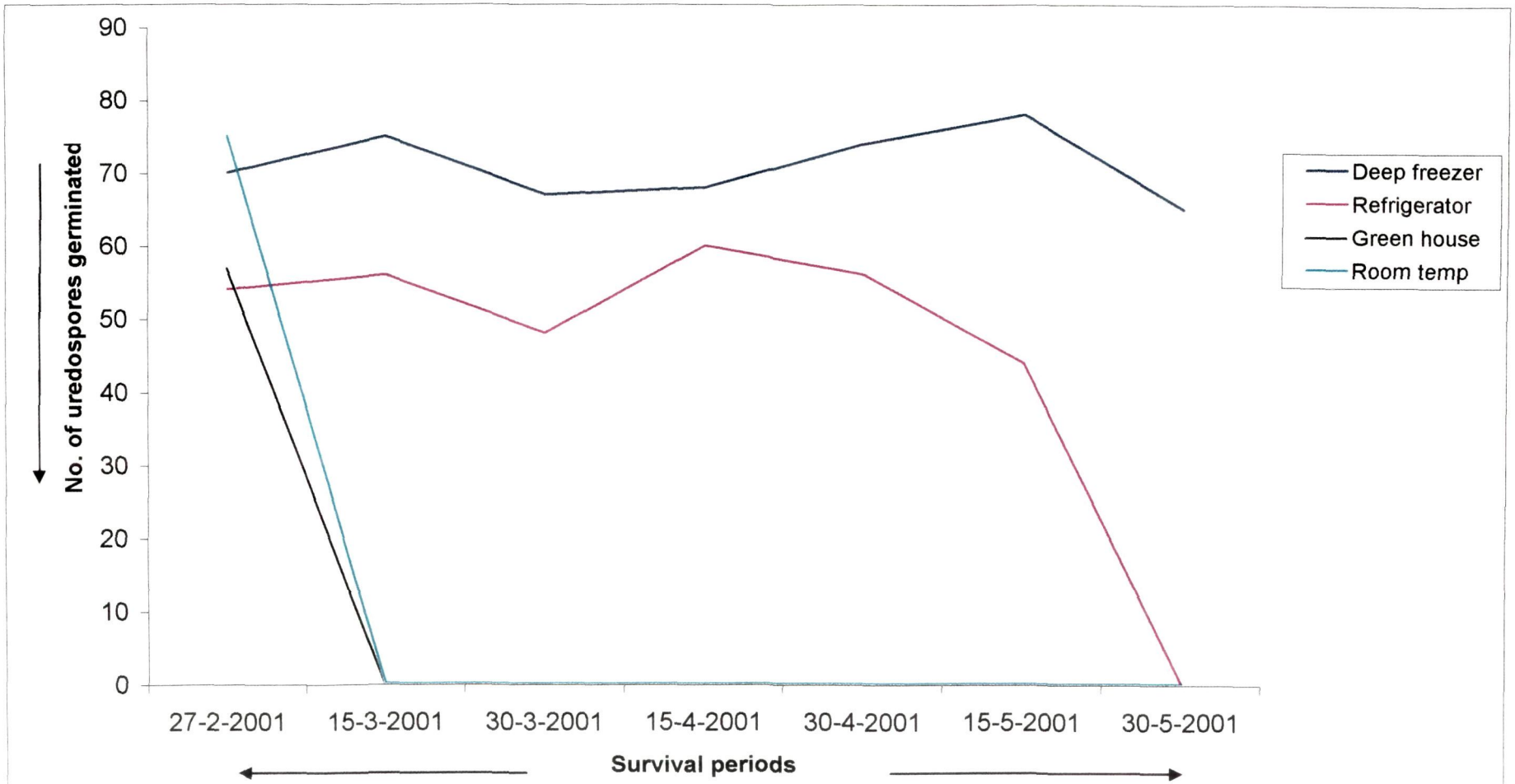

Fig.1:- Survival period of uredospores of *Puccinia graminis* var. *tritici* at different condtions of incubation

by refrigerator (41%) which survives for 75 days. The least average percent uredospore germination was recorded from green house (8%) and room temperature (9%) as indicated in table 2 and fig.2. There after, they lost the viability.

As shown in the table 2 and fig. 2 the survival period for leaf rust was high in deep freezer (90 days) followed by refrigerator (75days). It was observed that, the least survival periods of the uredospore were recorded in green house (15 days) and room temperature (15 days). The viability of uredospore after 75 days in refrigerator and 90 days in deep freezer reduced greatly.

MASS PRODUCTION AND MAINTENANCE OF INOCULA

This work was carried out both in the glass house and under field conditions for the mass production of inocula of both the rusts and maintenance during *rabi* 2001, as given in the 'Material and Methods'. Black stem rust and leaf rust susceptible varieties *viz.*, Pusa 4 and Agra local were used for mass production of inocula respectively. It was observed that, maximum uredospores were produced in the glass house and also under field conditions (Plate 3 a and b).

Maleic hydrazide was used in glass house for maximum production and it was observed that, maximum quantities of inocula were obtained by using it. Iron cage was used for getting maximum inocula production (plate 4). Individual pathotypes were maintained in glass house and deep freezer for further use (plate 5a and b).

Table: 2 - Survival period of uredospores of *Puccinia recondita* f.sp. *tritici* at different conditions of incubation.

Treatments	Per cent uredospore germination	Survival Period (days)
Deep freezer(-5°c)	63	90
Refrigerator(5°c)	41	75
Green house(32± 1°c)	8	15
Room temperature(27±1°C)	9	15

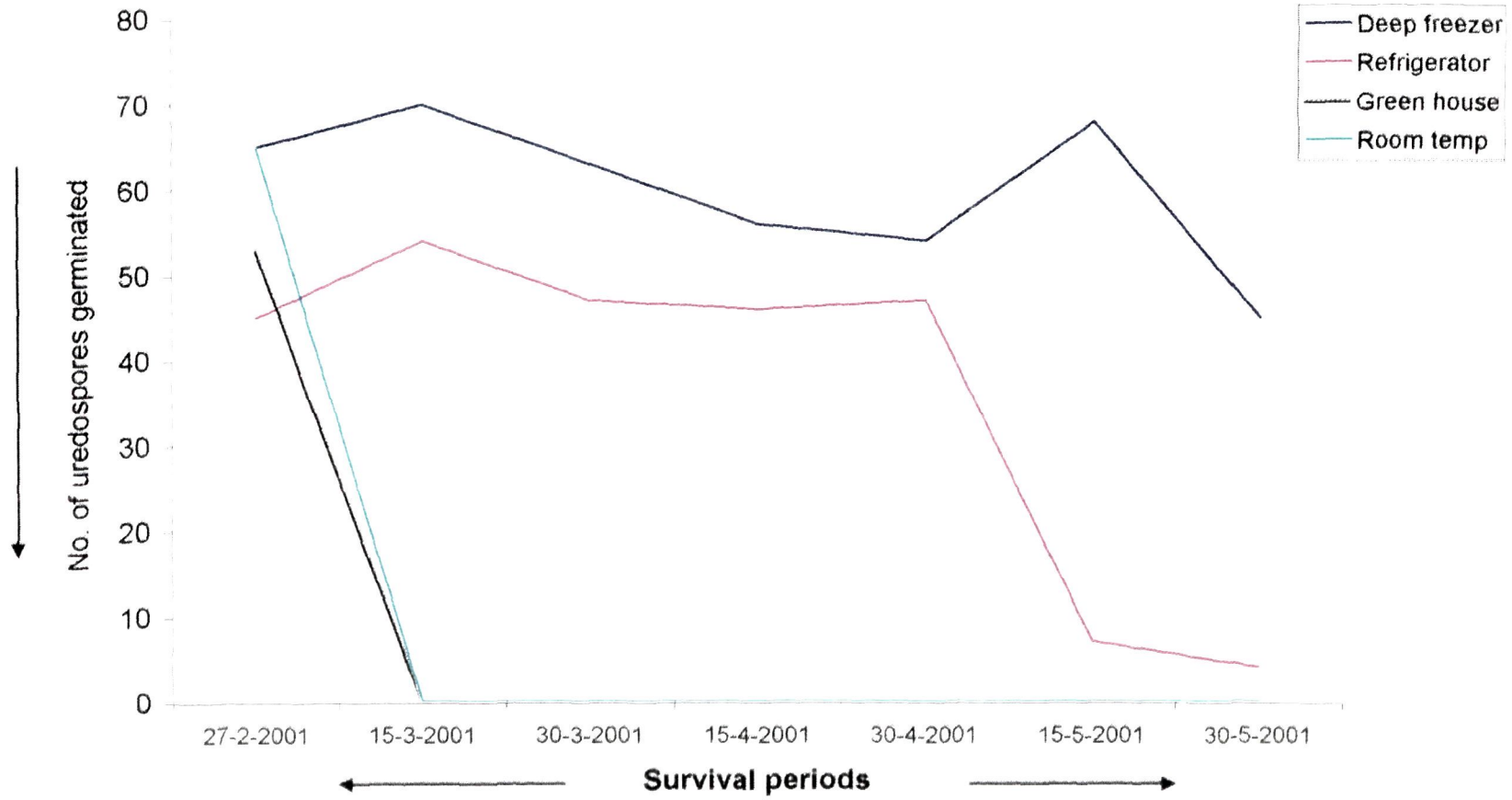

Fig. 2:- Survival period ofuredospores of *Puccinia recondita* f.sp. *tritici* at different condtions of incubation

Plate 2a: Photograph showing symptoms (Uredial stage) of leaf rust.

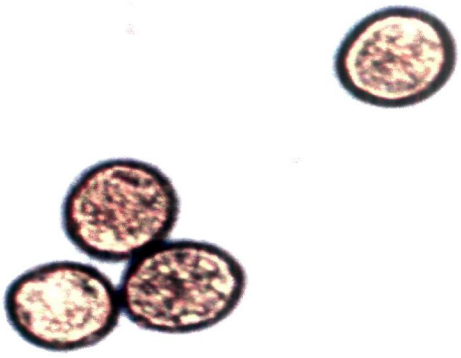

Plate 2b: Uredospores of leaf rust of wheat caused by *puccinia recondita* f.sp *tritici*.

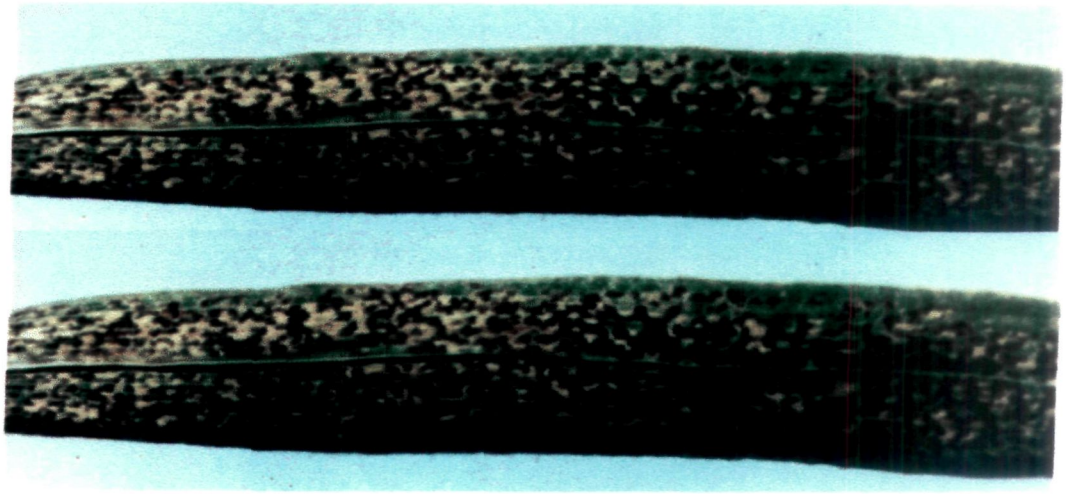

Plate 2c: Photograph showing telial stage of leaf rust.

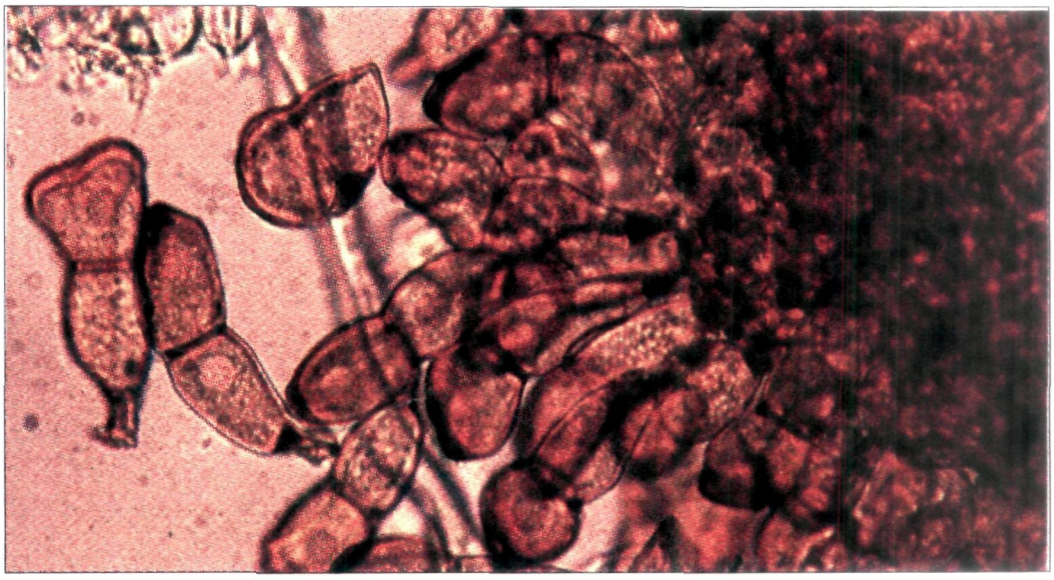

Plate 2d: Teliospores of leaf rust of wheat.

Plate 3a:Photograph showing multiplication of inoculum of stem rust in the field.

Plate3b: Photograph showing multiplication of inoculum of leaf rust in the field.

Plate 4 : Photograph showing multiplication of inocula in iron cage frame.

Plate 5a : Photograph showing maintenance of individual pathotype in a cage.

Plate 5b: Photograph showing maintenance of inocula in deepfreezer.

IDENTIFICATION OF PHYSIOLOGIC RACES OF *P. graminis var. tritici* and *P. recondita* f.sp. *tritici*

Samples of black stem and leaf rusts of wheat were collected from UAS, Dharwad during *rabi* 2000/2001 and samples were also collected from farmers fields of Belgaum and Dharwad districts during *rabi* 2001/2002. Such samples were taken to Regional Wheat Rust Research Station, Mahabaleshwar, Maharashtra for race identification studies in the glass house (plate 6a, b; 7a, b and 8a and b).

Eight samples of black stem rust and ten samples of leaf rust were collected from the wheat field of University of Agricultural Sciences, Dharwad. Samples were analyzed for their virulence identification and it was found that, races 15C (63G31) and 21A1 (20G21) were identified in stem rust samples as indicated in table 3. From the total number of isolates, 37.50 Per cent were race 15C (63G31) and 25 per cent were 21A1 (20G21). Three isolates could not be established due to unfavorable weather conditions.

In leaf rust samples group 77 was dominant in UAS, Dharwad. It was found that, 50 per cent of the identified races were 77-5(121R63-1). The other samples showed 10 percent, 10 percent, 10 percent, and 20 per cent for races 77-3 (123R55), 104-2 (21R55), 12-3 (49R37), 77-4 (125R23-1) respectively.

During *rabi* 2001/2002 samples collected from farmers fields from two districts *viz.*, Belgaum and Dharwad were analyzed. It was found that ,

Table: -3 Physiologic races of black stem rust of wheat (*Puccinia graminis* var. *tritici*) identified in some of the genotypes / varieties of wheat during *rabi* 2000/2001 at Dharwad.

Sample No.	Genotype/variety	Pathotype detected	
		Old name	New name
1	Gulab	N.E	N.E
2	Lal Bahdur	21A1	20G21
3	Local red	15C	63G31
4	GW 1183	N.E	N.E
5	N59	21A1	20G21
6	PUSA 4	15C	63G31
7	SONALIKA	N.E	N.E
8	VIJAY	15C	63G31

N.E- Not established

Table: 4 Physiologic races of leaf rust of wheat (*Puccinia recondita* f.sp.*trtici*) identified in some of the genotypes/varieties of wheat during *rabi* 2000/2001 at Dharwad.

Sample	Genotype/variety	Pathotype detected	
		Old name	New name
1	Agra local	77-5	121R63-1
2	C 306	77-4	125R23-1
3	Gulab	104-2	21R55
4	Lal Bahdur	77-5	121R63-1
5	Local red	77-4	125R23-1
6	GW 1183	77-5	121R63-1
7	A-9-30-1	77-3	123R55
8	Pusa4	77-5	121R63-1
9	sonalika	77-5	121R63-1
10	Vijay	12-3	49R37

Table: - 5 Physiologic races of leaf rust of wheat (*Puccinia recondita f.sp. tritici*) detected from farmer's fields of Belgaum and Dharwad districts during *rabi* 2001/2002.

Sample no.	District	Location	Variety	Reaction to leaf rust	Pathotype identified	
					Old name	New name
1	Belgaum	Bailhongal	DWR162	20MR	104-2	21R55
2		Naragundikoppa	DWR162	40MR	12-2	1R5
3		Naragundikoppa	'Keerti'	60MS	77-5	121R63-1
4		Siddasamudra	Local	60MS	77-3	123R55
5	Dharwad	Garag	Bijagayellow	60MS	77-5	121R63-1
6		Garag	DWR 162	100S	104-2	21R55
7		Tadkod	Local	40MS	104-2	21R55
8		Tadkod	Local	80MS	12-2	1R5
9		Tadkod	Bijagayellow	100S	12-5	109R37
10		UppinBetageri	DWR185	10MR	77-3	123R55

*- There was no appearance of stem rust during the season

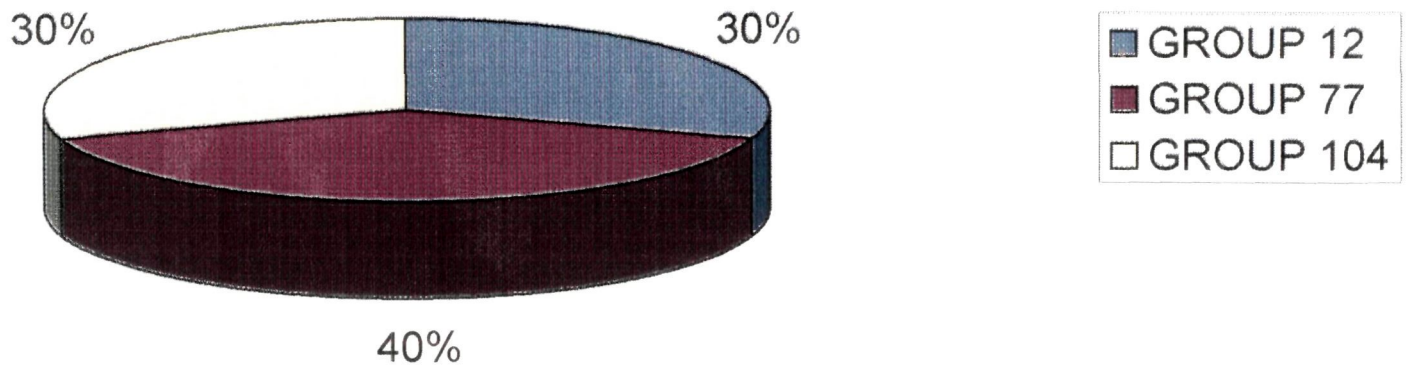

Fig 3:- Frequency and distribution of pathotype groups of *P. recondita* f.sp. *tritici* in Belgaum and Dharwad Districts during *rabi* 2001/2002

Plate 6a : Pot ready for seed sowing for virulence identification studies.

Plate 6b : Photograph showing sowing of seed for virulence identification studies.

Plate 7a : Inoculations of differentials for identification of virulences.

Plate 7b: Photograph showing humidifying chamber for creating humidity for infection.

Plate 8a: Photograph showing set of differentials on 12th day after inoculation to identify the virulences.

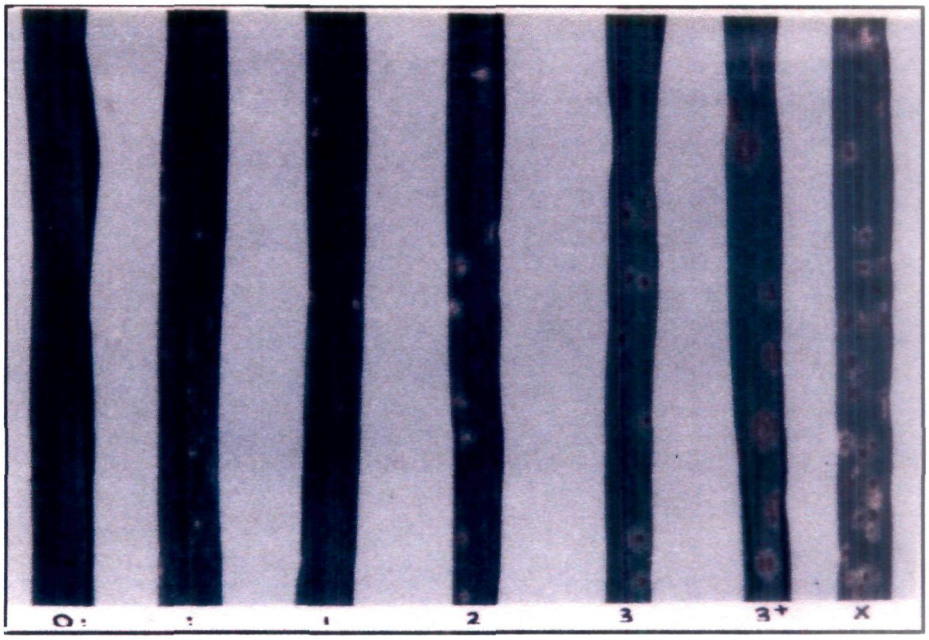

Plate 8b: Photograph showing various infection types for leaf rust.

race group 77,104 and 12 were recorded as shown in table 5 and fig. 3 with the frequency of 40 percent, 30 percent and 30 percent respectively. The infection types were severe from the samples collected. Three groups were identified both at Belgaum and Dharwad districts. Race 12-2(1R5) and 104-2(21R55) of leaf rusts were detected from DWR162 from 'Naragundikoppa' and 'Bailhongal' area of Belgaum. The race detected at Dharwad (Garag taluk) in the variety DWR162 was 104-2(21R55). The stem rust did not appear during the season.

PERFORMANCE OF WHEAT VARIETIES AGAINST BLACK STEM AND LEAF RUSTS

In the present study, 22 wheat varieties received from All Indian Wheat Improvement Project, Dharwad were tested against black stem and leaf rusts at Ugar Khurd during *rabi* 2001-2002 under natural conditions as described in 'Material and Methods' (plate 9a,b and 10a,b). The severity of black stem and leaf rusts were recorded. Further, after maturity 1000 grain wt. was also recorded and presented in table 6. The results from the table 6 indicated, there was a significant difference in yield among varieties tested at P=0.01 and the R^2 value is 0.413 which showed 41 percent of the yield variation is due to leaf rust infection.

There was considerable correlation between disease and yield. So, the regression equation formulated was Y=-0.1499x +42.04. Varieties HI-8498, DWR-1006, MACS-2846 showed very low average coefficient of infection *viz.*, 2, 2, 2 respectively. The 1000 grain weights of these varieties

Table: -6 A regression analysis of yield and leaf rust reaction of commercially grown varieties during *rabi* 2001/2002 at Ugar Khurd.

Varieties	Average Coefficient of Infection(ACI)	1000 grain Wt (g)	Rank
C306	100	29.8	14
DDK-1013	8	43.5	5
DWR1006	2	49.9	2
DWR162	80	25.1	17
DWR195	16	44.4	4
DWR225	8	34.9	12
GW-273	16	40.5	6
GW-322	10	32	13
HD-2189	16	39	9
HD-2285	8	43.5	5
HD-2329	80	36.2	10
HD-2428	60	36	11
HI-617	80	29.4	15
HI-8498	2	51.9	1
HP-1761	16	24	18
HS-295	8	40.2	7
HW-2004	16	39.7	8
LOK-1	16	43.5	5
MACS-2496	80	27.1	16
MACS-2846	2	45.3	3
PBW-223	8	36	11
PBW-848	16	36	11

R^2=0.413; P=0.01(Significant level)

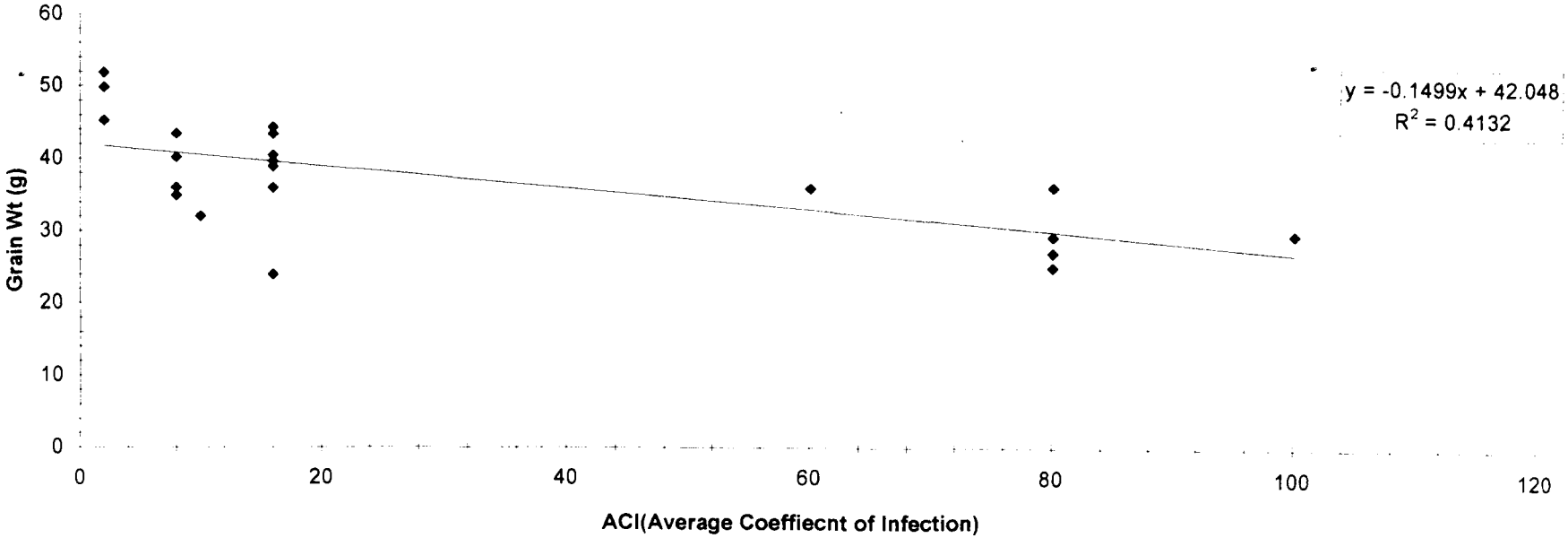

Fig 4 :- The grain yield plotted againist leaf rust of wheat

Plate 9a. Field performance of varieties against stem and leaf rust of wheat during rabi 2001/2002.

Plate 9b: Photograph showing comparison between resistant and susceptible varieties of wheat.

Plate 10a. Photograph showing severity of rusts affected field

Plate 10b. Photograph showing rust free field.

were 59.90, 49.90 and 45.30 respectively. Wheat varieties *viz.*, C-306 and DWR-162 were severely affected by leaf rust and expressed high average coefficient of infection *viz.*, 100 and 80 respectively. During the season no stem rust has appeared at Ugar Khurd. As indicated in fig. 4, most of the point was near to the line which showed there was a negative correlation between the yield and the disease. The performance of 22 commercially grown wheat varieties were tested at Regional Wheat Rust Research Station, Mahabaleshwar (Maharashtra) during *rabi* , 2001-2002 for reaction to black stem and leaf rusts. It was observed that, varieties *viz.*, DDK 1001, L.Khapli and NIAW15 showed resistant reaction with terminal severity of 5R, 5R, 5R for black stem rust and 5MR, 5MS, and 5MR for leaf rust respectively as given in table 7. It was found that, varieties *viz.*, N59, DWR162 and DWR39 were highly susceptible with terminal severity of 100S, 80S and 80S for black stem rust and 90s, 80s, 60s for leaf rust respectively. Varieties *viz.*, HD 4502 and MACS 2846 showed moderately resistant reaction for black stem rust with terminal severity of TMR and 10MR respectively as indicated in table 7.

Reaction of Sr and Lr isogenic lines to stem and leaf rusts under field conditions.

It is necessary to use isogenic Sr and Lr lines in breeding programme to develop resistant varieties against wheat rusts. The plant breeders can use known lines, in order to incorporate into the varieties.

The performance of 43 Sr and 30 Lr isogenic lines to black stem rust and leaf rust race mixtures were tested under artificial epiphytotic

Table: - 7 Reaction of some commercially grown varieties of wheat at Regional Wheat Rust Research Station, Mahabaleshwar during *rabi* 2001/2002.

Varieties	Stem rust reaction	ACI	Leaf rust reaction	ACI
Bijaga Red	60S	60	10MR	4
DDK1001	5R	1	5MR	2
DDK1009	40S	40	20MR	8
DWR 162	80S	80	80S	80
DWR 195	40MR	16	60S	60
DWR 39	80S	80	60S	60
HD 2189	20S	20	15MS	12
HD 2278	40MS	32	30S	30
HD 2380	60S	60	50S	50
HD 2501	20MS	16	20S	20
HD 4502	TMR	0.2	5MS	4
L. KHAPLI	5R	1	5MS	4
MACS 1967	20S	20	20MS	16
MACS 2496	20MS	16	60S	60
MACS 2846	10MR	4	10MS	8
MACS 9	60S	60	50S	50
N59	100S	100	90S	90
NI 146	80S	80	50S	50
NI 5439	40S	40	TMS	0.8
NIAW 34	10MS	8	5MS	4
NIAW 15	5R	1	5MR	1
PBN 142	60MS	48	TMS	0.8

conditions in the field during *rabi* 2001/2002 at Regional Wheat Rust Research Station, Mahabaleshwar as explained in 'Material and methods'

The terminal severity for both stem and leaf rusts was recorded as per the scale of Loegering (1959) and data are presented in the table 8 and 9.

It was noticed that, the performance of Sr and Lr isogenic lines to both black stem and leaf rusts were varied. The Sr isogenic lines showed 0-tMS reaction to stem rust races and 0-80S to leaf rust races.

Some of the Sr lines showed immune reaction to stem rust pathogen races. Few Sr lines showed immune reaction for both stem and leaf rust races. They are *viz.*, Sr12, Sr16, Sr7b+Sr9a+Sr9d, Sr24 (Agent) Sr25 (Agatha), Sr32, Sr33 and Sr35. The reaction of 31 Lr lines for black stem and leaf rust races was also carried out as shown in table 9. It was found that, 0-80S range for stem rust and 0-20MS reactions for leaf rust were recorded. Lr lines *viz.*, Lr14A, Lr16,Lr12(Exchange),Lr19(Agatha), Lr19, Lr22b,Lr24 and Lr30 showed immune reaction for both black stem and leaf rusts as shown in table 9. These lines which showed 0 (immune) reactions did not produce uredia and no symptoms were observed. During this season, Lr9 showed TMR reaction for leaf rust, which needs further investigation for confirmation for new pathotype/pathotypes.

Postulation and documentation of genes

This study was carried out in the glass house at Regional Wheat Rust Research Station, Mahabaleshwar to postulate and document Sr and

Table: - 8 Reaction of Sr lines for black stem rust and leaf rust under field conditions during 2001/02 at Regional Wheat Rust Research Station, Mahabaleshwar .

Sr Lines	Reaction to Stem rust	Reaction to Leaf rust
Sr-2	TMR	5MR
Sr-5	TMS	5MR
Sr-6	0	TMS
Sr-7	5S	60S
Sr7b+Sr10	5S	40S
Sr 7b+Sr17	0	80S
Sr7b+Sr9a+Sr9d	0	0
Sr-8	TS	80S
Sr-9a	5S	60S
Sr-9e	0	30S
Sr9e(conder)	TMS	20S
Sr-9g	5S	60S
Sr9g+Sr 16	TMS	TMR
Sr9g+Sr26	TMS	40S
Sr-10	TMS	60S
Sr-11(Gabo)	TMS	60S
Sr11(Tasta)	TS	5S
Sr-12	0	0
Sr-13	0	40S
Sr-14	0	30S
Sr15(Norkd)	TMR	40S
Sr-15(Thew)	0	TMR
Sr-16	TS	0
Sr-16	0	0
Sr17	0	20MS
Sr21(Einkorn)	TMR	30S
Sr23	5S	0
Sr24(Agent)	0	0
Sr24A	TMS	20MS
Sr25	TMS	80S
Sr25(Agatha)	0	0
Sr26(Kite)	TMS	80S
Sr27(Coomng)	0	TMR
Sr29	TMS	20MR
Sr30	TS	20S
Sr31(Selkirk)	5S	TS
Sr31	TS	10MS
Sr32	0	0
Sr33	0	0
Sr34	0	60S
Sr35	0	0
Sr36	0	10MS
Sr37	0	80S

Table: - 9 Reaction of Lr lines for black stem rust and leaf rust under field conditions during *rabi* 2001/02 at Regional Wheat Rust Research Station, Mahabaleshwar.

Lr lines	Reaction to Stem rust	Reaction to Leaf rust
Lr1	0	60S
Lr2b	0	10S
Lr2c	TMS	5S
Lr2d	5S	0
Lr3(Democrat)	0	60S
Lr9	TMS	TMR
Lr10	TMR	30S
Lr10(Federation)	20S	80S
Lr10+Lr22	20MS	80S
Lr12(Copal)	TS	5MR
Lr12(Exchange)	0	0
Lr13	TS	TMS
Lr14A	0	0
Lr14B	TS	0
Lr15	0	40S
Lr15(Kenya)	TS	20S
Lr16	0	0
Lr16(Timvera)	TS	5MR
Lr19	0	0
Lr19(Agatha)	0	0
Lr21	0	TMR
Lr22A	0	10MR
Lr22b	0	0
Lr23	TS	60S
Lr24	0	0
Lr25	TS	80S
Lr26	0	60S
Lr27	TS	20MR
Lr29	TS	0
Lr30	0	0

Lr lines in the varieties received from Dr. Sanjaya Rajaram laboratory, Wheat Improvement Project, University of Agricultural Sciences, Dharwad (plate 11a,b and 12).

The infection types (ITs) displayed by the tester Sr and Lr lines and commercially grown wheat varieties when inoculated with 12 and 13 pathotypes of *Puccinia graminis var. tritici* and *P. recondita f.sp. tritici* are listed in table 10 and 11 respectively. The varieties *viz.*, DWR 2006, NP 200, DDK 1001, DDK 1009, DDK1019 and DDK 1020 appeared to carry sr9e, sr7b, sr9e, sr7b, sr7b and sr7b respectively with an additional unknown gene. Sr gene/genes from DWR225 and DWR1006 could not be postulated. The varieties *viz.*, DDK1001, DDK1019 and DDK1022 were found to carry gene combination of Lr23+Lr26, 23+Lr26 and Lr10+Lr26 respectively with an unknown additional gene. Whereas, DWR 225 carries Lr 26 with an unknown additional gene and DWR 2006 possessed gene combination (Lr13+Lr23). But Lr genes from DWR 1006, NP200 and DDK1009 could not be postulated.

Table:- 10 Reaction of seedlings of wheat varieties against twelve pathotypes of *P.graminis var. tritici* and postulation of Sr genes.

Sl.No.	**Variety /Sr lines**	**Reaction against Pathotype**											Postulated Sr Gene/Gene's
		79 G 31 (11)	**203 G 15** (11A)	**20 G 21** (21A1)	**75 G 5** (21A2)	**62 G 29** (40A)	**62 G 29-1** (40-1)	**19 G 35** (42)	**7 G 35** (42B)	(42B3)	**38 G 18** (117A1)	**33 G 3** (117-2)	**166 G3** (117-4)	
1	DDK1001	;	1,2	0;	2,3	0;	1,2	3+	; -	0;	;	0;	1+	Sr9e+
2	DDK1009	;1-	2,3	0;	3+	;1	;	0;	;1	;1	;	0;	;1	Sr7b+
3	DDK1019	0;	3+	0;	2	;1	;	0;	0;	1+	;1-	0;	;1	Sr7b+
4	DDK1020	1	*2+*	3+	*3+*	*;1*	1,2	3+	;1	*;1*	;	*0;*	*;1*	Sr7b+
5	DWR 225	;1	;1	;	;1	;1	;	0;	;1	;1-	0;	;1	;	— *
6	DWR1006	;	;	0;	;1	;1	2,2+	;1	;1	;1	0;	;1	1,2	—
7	DWR 2006	;1-	;1	;	;12	;1	1+	;	;	;1+	1,1+	3+	;1	Sr9e+
8	NP200	;1	1,2	1+	3+	;	;	3	;	;1	1	0;	;1	Sr7b+
	Sr2	2	3+	3+	3+	3+	3+	3+	;	;	;	3+	3	
	Sr-5	3+	3+	0;	;	3+	3+	0;	;1	1,2	0;	0;	0;	
	Sr7b	3,3+	3+	3+	3+	3+	3+	3+	3+	1,2	1+	3+	3	
	Sr8b	2,3	3+	3+	3+	3+	1,2	0;	1,2	1,2	2+	0;	2	
	Sr9b	2,3	3+	0;	11+	3+	3+	3+	3+	1,2	3+	0;	3+	
	Sr9e	1,1+	1+	1,2	1,1+	1+	3+	;1	;1	;1	3+	3+	3+	
	Sr11	3+	1,2	3+	;1	;1	3+	1,2	3+	;1	3+	;	3+	
	Sr24	;1	2,2+	0;	1,2	1,2	;	0;	;	0;	;	0;	;1	
	Sr31	;1+	1,2	1+	1,1+	1,1+	;	;1	;	;1	;	0;	;1	

*- Sr genes from DWR 225 and DWR 1006 are not postulated

Table: - 11 Reaction of seedlings of wheat varieties against thirteen pathotypes of *P.recondita f.sp.tritici* and postulation of Lr genes.

Sl. No.	Variety / Lr lines	Reaction against Pathotype													Postulated Lr gene/genes
		0 R 8 (11)	**5 R 37** (12-1)	**1 R 5** (12-2)	**69 R 13** (12-4)	**45 R 31** (77)	**109 R 31** (77A)	**109 R 31-1** (77-2)	**125 R 23-1** (77-4)	**21 R 31** (104A)	**29 R 23** (104B)	**21 R 55** (104-2)	**21 R 63** (104-3)	**0 R 9** (106)	
1	DDK1001	1,2	;1	;1	2	;	;1	;	;12	;1	3+	3+	1,2	;1	Lr23+26+
2	DDK1009	;	;	;1	2+	;	;1	;1	0;	1,2	;	;	;	;1	-
3	DDK1019	1+	1,2	;1	;1	;	;1	;1	3+	;1	;1	2	3+	;1	Lr23+26+
4	DDK1022	1,2	;1	;1	33+	;1	2	;1	3+	2	1,2	;1	3+	2	Lr10+26+
5	DWR225	;	3+	;	0;	0;	0;	0;	;	;	0;	3+	;	0;	Lr26+
6	DWR1006	;1	;	1+	;1	;	;	;	;	;1	;	;1	;12	;	- *
7	DWR2006	;12	;1	1,2	2-	;	3+	;	;1	1,2	;1	;1	3+	;	Lr13+23
8	NP200	2+	;	2	1,2	;1	1,2	1,2	;12	;	;	1	1	1	-
	Lr1	;	1,2	;1	;	3+	3+	3+	3+	3+	3+	3+	3+	;	
	Lr2a	;	;	1,2	1,2	3+	3+	3+	3+	3+	3+	3+	3+	;	
	Lr2c	1,2	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	
	Lr10	;	;1	;	3+	;1	3+	3+	3+	;1	,1	;	;	;	
	Lr13	;	2	2	1,2	3+	3+	3+	3+	1,2	3+	1,2	1,2	;	
	Lr14a	;	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	3+	;	
	Lr15	1,2	1,2	2	2	3+	3+	3+	3+	2	1,2	2	1,2	;	
	Lr18	;	3+	;	3+	3+	3+	3+	3+	3+	3+	33+	33+	;	
	Lr19	;	;	;1	;	1,2	0;	0;	;1	;	;1	;1	2	;1	
	Lr23	2	2	3+	;	;	1,2	3+	3+	2	3	3+	3+	;	
	Lr24	;	;	;	;1	;	;1	;	;1	;1	;	;1	;1	;	
	Lr26	;	3+	;	;	;1	;	;	;	;	;	3+	3+	;	
	Lr34	;	3+	3+	3+	3+	2+	33+	33+	3+	3	3+	3+	2	

- Lr genes from DWR 1006, NP 200 and DDK 1009 are not postulated

Plate 11a: Glasshouse for stem rust

Plate11b: Glasshouse for leaf rust study.

Plate 12: Photograph showing inoculation of seedlings for postulation of genes in wheat varieties.

DISCUSSION

V. DISCUSSION

Wheat (*Triticum* spp.) is an important crop of the world grown in larger area and produces more tonnage of food than any other cereal. History reveals that, wheat cultivation converted men from hunters and food gatherers into farmers.

The rusts are responsible for the considerable damage to the wheat crop. The losses caused due to rusts vary from region to region. Stem rust which is caused by *Puccinia graminis var. tritici*, though prevalent all over the country, normally appears in epidemic form only in southern, central and eastern part of the country, where normally high temperature prevails during the crop season. However, leaf rust caused by *P. recondita f.sp. tritici* is a serious problem throughout the country.

For effective usage of vertical resistant genes, there is a need for knowledge of perpetuation of the pathogen, because it is highly influenced by weather factors *viz.*, temperature and humidity.

Nowadays, attention is given to race specific resistance because of the shifty nature of rust pathogens. Virulence of rust pathogen is changing time to time whenever, there is pressure for incorporation of resistant gene or genes. Hence, virulence monitoring should be done through effective race analysis procedure.

The future strategy of managing these pathogens is through host plant resistance because; it is an important tool to minimize the inoculum build up and help in keeping the pathogen at bay. Knowledge

on postulation and documentation of Sr and Lr genes and diversity of resistance in wheat varieties are important in breeding programme for the stability of the pathogen. Hence, investigations were carried out at Dr. Sanjay Rajaram Wheat Laboratory, Main Research Station, University of Agricultural Sciences, Dharwad (Karnataka state) and also at Regional Wheat Rust Research Station, Mahabaleshwar (Maharashtra state).

In the present study, stem rust and leaf rust affected samples were analyzed for the survival of uredospores at different incubation levels as stated in the objectives. The results revealed that, high temperature reduced the viability of uredospores and they cannot survive for a longer period. Whereas, the uredospores can survive for a longer period in cooler temperatures *viz.*, deep freezer and refrigerator.

The studies revealed that, stem rust can survive in the northern hills throughout the summer months. At Bhowali (5200 ft.a.s.l.) crop was sown in September and inoculated in October and stem rust infection developed. However, it did not spread even to the next rows of the same cultivar in the subsequent months. Apparently, the pustules remained inactive. Such inactive or dormant pustules can be found on wheat even in peak winter months in northern hills (Joshi, 1986).

Mehta (1940) has shown that due to high temperature prevailing in the plains of India during summer months, wheat rusts in general, can not survive, while they could over summer in cooler climate of the hills on self sown plants, ratoon tillers and also on the regular summer crop of Nilgiri and Pulney hills. Uredospores of rusts can survive on off-season

wheat (Mungari wheat) of Karnataka because of cooler temperatures prevailing during that period (Kulkarni, 1984).

Earlier studies conducted on the epidemiology of cereal rusts in Indo-Pakistan sub-continent showed that, the uredospores of the three rusts do not survive at high summer temperatures of the plains and over-summer in stubbles and volunteer wheat plants in Himalayas. (Bhatti and Ilyas, 1986).

Gupta and Srivastava (1973), Eversmeyer and Kramer (1989) also reported similar type of results. In the present investigation also high temperatures reduced the viability of uredospores of both the rusts.

The rusts are obligate parasites or biotrophs and difficult to multiply in the laboratory in culture media like facultative or saprophytic fungi. so, there is a need to multiply these pathogens in bulk for screening of varieties for resistance. Presently, resistant varieties are becoming the only options in the management of wheat rusts. In order to achieve this goal, germplasm will have to be screened under artificial epiphytotic conditions. Hence, inocula of both the rusts multiplied in large quantities under controlled environmental conditions.

The experience under Indian conditions showed the difficulty of maintaining wheat rust culture in the plains and also creating artificial epiphytotics in the experimental plots (Joshi *et al.*, 1988).

The present study was carried out both in the glass house and also under field conditions at Regional Wheat Rust Research Station,

Mahabaleshwar for mass production and maintenance of inocula of both the rusts. It was observed that, maximum uredospores were produced in the glass house under controlled temperature and humidity conditions. The use of 0.02 per cent maleic hydrazide increased the production of uredospores both for black stem and leaf rusts by making the plants more susceptible to the rust pathogens. These results are in accordance with the work of Joshi (1965 and 1968) in case of stem and leaf rusts of wheat in India.

Secondary multiplication of inocula was done under field conditions in Iron frame cage covered with wet muslin cloth and tarpatein, for maximum multiplication of inocula. It was observed that, large quantity of inocula was obtained through this method. Similar studies were carried out by Joshi (1968) and showed that constructing temporary alkathene houses for the production of maximum inocula is a feasible venture.

The study on the variations and identification of physiologic races of rusts was carried out with a view of assisting plant breeders in development of rust resistant crop varieties. This information will help the plant breeders to develop resistant varieties against prevailing physiologic races of both the rusts. Further, the resistant genetic stock could be maintained for further use in the breeding programme.

Mehta (1940) initiated the research on the cereal rusts and systematic virulence analysis in India during 1923 and 1931, respectively.

In the present investigation, the virulences were identified by following new virulence identification system proposed by Nagarajan *et al* (1983). It was found that, races 15C (63G31) and 21A1 (20G21) of black stem rust (*Puccinia graminis var. tritici*) were predominant at UAS, Dharwad wheat fields. Mehta (1941) reported that, these races existed 60 years back in India and the results confirmed that there may be some modification from the previous race *viz*; 15 and 21. It was observed that, group 77 was dominant in leaf rust (*P. recondita f.sp. tritici*). But, leaf rust samples collected from Belgaum and Dharwad districts showed only race group *viz.*, 77, 104 and 12. It was indicated that, race group 77and 104 are the dominant race flora in Karnataka state. Hence, these results have provided the information to plant breeders to develop wheat varieties resistant to these prevailing races of stem and leaf rusts. Plant breeders can reorient their breeding programme based on this information.

The pathotype 121R63-1(77-5) of leaf rust showed maximum frequency of 41per cent. Kulkarni (1978 and 1979) also reported high frequency of leaf rust races *viz.*, groups 77 and 162 from Karnataka state. He stressed that group 77 is the most predominant one in the state. He suggested the development of resistant varieties against these groups of races. The dominance of group 77 was also reported by several workers in India (Joshi *et al.*, 1970; Nayar *et al.*, 1975; Kadam *et al.*, 1975, Nargund, 1989; Nayar *et al.*, 1996 and Hasabnis, 1998).

The cost effective, eco-friendly, economical and less risky method of managing the rust pathogens is the use of resistant varieties. With this objective in mind the present study was carried out at Ugar Khurd and Mahabaleshwar during *rabi* 2001-2002 to know the performance of commercially grown varieties of wheat. The results indicated that, there was a negative correlation between the yield and rust diseases. Similar results were reported by Mishra et al., 1970; Naik et al., 1974. It was observed that varieties C 306 and DWR 162 showed high level of infection of leaf rust. These results are also in agreement with the work of Navi (1986) and Hasabnis (1998).Hence, HI 8498, DWR1006 AND MACS2846 showed resistant reaction to leaf rust.

Studies on the identification of resistant genes and their relation ship with known genes have been attempted. This aspect of research has significance to plant breeders in their endeavour to develop varieties with stable resistance (Kulashresta, 1986). The isogenic lines *viz.*, Lr9 and Lr19 have been reported to be immune till to date to all the known Indian races of leaf rust. (Reddy, 1974; Kulkarni, 1979, Sawhney *et al.*, 1977; Saadovi, 1985, Casulli and Siniscalco; 1987).

In the present study, on the performance of Sr and Lr lines against black stem and leaf rust pathogen was carried out. It was found that, Sr12, Sr24, Sr25, Sr16, Sr32, Sr33 and Sr35 were free of stem rust infection. Similarly, Lr19 showed immune reaction to stem and leaf rusts. During rabi 2001/2002, it was observed that, infection of stem and leaf rusts was recorded on Lr9 line, which needs further investigation. The

above results are in accordance with the work of Kulkarni (1979 and1980), Nargund (1989) and Hasabnis (1998). These isogenic lines could be used to incorporate resistant genes into commercial varieties of wheat against rust pathogens.

The identification of resistance genes and the relationship with known genes has great relevance to plant breeders in their endeavour to breed the varieties for greater stability. The infection types conditioned by the gene to particular pathotypes are useful in identifying resistance genes.

Nagarajan *et al.*, (1984) identified the different types of resistant genes by selecting appropriate pathotypes by following gene matching technique in large number of wheat genotypes. McIntosh *et al.*, (1995) catalogued resistance genes to three rusts of wheat.

In the present investigation with the inoculation of different pathotypes and by matching the infection types of Sr and Lr tester lines, it was possible to postulate Sr and Lr lines from eight commercially grown wheat varieties. It was revealed that, these varieties carry Sr9e and Sr7b, with an additional unknown gene except DWR225 and DWR 1006. Sr gene from DWR225 and DWR1006 are not postulated because both the genotypes produced 'R' reaction against all the tested pathotypes. It is difficult to state whether resistance is due to Sr24 and/or Sr31.

The varieties DDK1001, DDK1019 and DDK1022 were found to carry genes in combination of Lr 23+Lr26, 23+Lr26 and Lr10+Lr26 respectively, with an unknown additional gene. Lr genes from DWR 1006,

NP200 and DDK1009 were not postulated. The reaction produced by these varieties are resistant type against all the tested pathotypes. Similarly, reactions noticed on Lr9, Lr19 and Lr24 are resistant type against all the tested pathotypes. Hence, it is not possible to state which of the gene among Lr9, Lr19 and Lr24 are responsible for imparting resistance in genotypes DWR 1006, NP200 and DDK1009.

Future Line of work

1. The virulence analysis should cover other wheat growing areas of the Karnataka for effective deployment of genes.

2. Presently, race analysis is based on host: pathogen interaction, so, there is a need to identify the virulence by using biotechnological methods in addition to host: pathogen interaction for a greater accuracy.

3. *Identification of molecular markers linked to the target resistance* genes. This will facilitate the marker assisted selections for resistance to rusts.

4. The different genetic approaches should be addressed with other agronomic manipulation for effective management of both the rusts.

SUMMARY

VI. SUMMARY

Black stem and leaf rusts of wheat caused by *P. graminis* var. *tritici* and *P.recondita* f.sp. *tritici* respectively, are the notorious wheat pathogen, which are the major constraints in wheat production.

The present investigations on black stem rust and leaf rust of wheat include: perpetuation of the pathogens at different condition of incubation, analysis of the races of rusts prevailing in the selected districts, management of diseases through host plant resistance and gene postulation and documentation. These experiments were conducted during *rabi* 2000-2001 and 2001-2002 at Department of Plant Pathology, Main Research Station, University of Agricultural Sciences, Dharwad, Karnataka; Regional Wheat Rust Research Station, Mahabaleshwar, Maharashtra and Ugar Sugar Works, Pvt. Ltd., Ugar Khurd, Karnataka. The results of the study are summarized hereunder.

The survival period of uredospores of black stem and leaf rusts was more in deep freezer (90days) and refrigerator (75 days), but their survival period in glass house and room temperature was very short i.e., 15 days each.

Maximum amount of uredospores of black stem and leaf rusts were multiplied in the glass house under controlled conditions by using maleic hydrazide at 0.02 percent. It was also found that maximum uredospore inocula was produced under field condition also.

The investigation on the physiologic races existing in Dharwad and Belgaum districts revealed that, race group 15C (63G31) and 21A1 (20G21) of black stem rust were dominant at the farm of University of Agricultural Sciences, Dharwad and race group 77 and 104 of leaf rust were dominant in farmers' field of Belgaum and Dharwad districts and also in farm of University of Agricultural Sciences, Dharwad.

Twenty two commercially grown varieties of wheat were tested at Ugar Khurd showed that, there was a strong negative correlation between leaf rust and yield, where 41 percent of the variation observed in yield was due to the disease. The varieties *viz.,* DWR1006 and HI-8498 showed more thousand grain weight as compared to others and there Average Coefficient of Infection (ACI) for leaf rust was very low. The varieties *viz.*, DWR162, HP1761 and MACS-2496 showed lesser thousand grain weight as compared to the rest of the varieties.

Among 22 commercially grown varieties tested at Regional Wheat Rust Research Station, Mahabaleshwar; DDK 1001, L.Khapli and NIAW 15 showed terminal severity of 5R, 5R, 5R for stem rust and 5MR, 5MS, 5MR for leaf rust, respectively. Whereas, DWR 162 showed the terminal severity of 80S for both stem and leaf rusts.

The study on postulation of Sr and Lr genes on eight commercially grown varieties of wheat revealed that, DWR 2006 and DDK1001 carry Sr 9e and varieties *viz.*, NP200, DDK1009, DDK1019 and DDK1020 were found to carry Sr7b with an additional unknown gene. These eight varieties were found to carry Lr genes viz., Lr26, Lr13, Lr23 and Lr10 as

singly or in combination except varieties viz., DWR1006, NP200 and DDK1009 which could not be postulated.

Both the pathogens are shifty enemies and take heavy toll of the crop every year. Hence, it is essential to combat these dreaded diseases through various genetic approaches and strategies.

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*Original not seen.

PERPETUATION, PHYSIOLOGIC SPECIALIZATION AND MANAGEMENT OF STEM AND LEAF RUSTS OF WHEAT

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ABSTRACT

Black stem and leaf rusts of wheat caused by *P. graminis* var. *tritici* and *P.recondita* f.sp. *tritici* respectively, are the notorious wheat pathogens, which are the major constraints in wheat production. Experiment were carried out to know the survival period of the uredospores at different incubation conditions, the existence of races in some locality of Karnataka and management of these rusts.

The survival period of uredospores of black stem and leaf rusts were more in deep freezer (90days) and refrigerator (75 days), but their survival period in glass house and room temperature was very short i.e., 15 days each.

The study on the physiologic races existing in Dharwad and Belgaum districts revealed that, race group 15C (63G31) and 21A1 (20G21) of black stem and race 77-5 (121R63-1) and 104-2 (21R55) of leaf rust were predominant.

Out of 22 commercially grown varieties tested, DDK1001, L.Khapli and NIAW 15 showed terminal severity of 5R, 5R, 5R for stem rust and 5MR, 5MS, 5MR for leaf rust, respectively. Whereas, DWR162 showed the terminal severity of 80S for both stem and leaf rusts.

The postulation of Sr and Lr genes on eight commercially grown varieties of wheat revealed that, DWR 2006 and DDK1001 carry Sr 9e and varieties *viz.*, NP200, DDK1009, DDK1019 and DDK1020 were found to carry Sr7b with an additional unknown gene. These eight varieties were found to carry Lr genes viz., Lr26, Lr13, Lr23 and Lr10 as singly or in combination except varieties viz., DWR1006, NP200 and DDK1009 which could not be postulated.