

**ASSESSMENT OF GREENGRAM GENOTYPES FOR
PARTIAL RESISTANCE TO POWDERY MILDEW
(*Erysiphe polygoni* DC.) AND CHARACTERIZATION
OF RESISTANCE**

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**DEPARTMENT OF PLANT PATHOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
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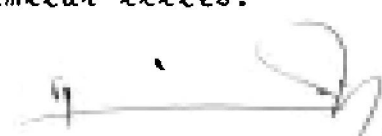
*Affectionately Dedicated to
My Beloved Parents*

DEPARTMENT OF PLANT PATHOLOGY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

C E R T I F I C A T E

This is to certify that the thesis entitled "ASSESSMENT OF GREENGRAM GENOTYPES FOR PARTIAL RESISTANCE TO POWDERY MILDEW (Erysiphe polygoni DC.) AND CHARACTERIZATION OF RESISTANCE." submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (AGRICULTURE) in PLANT PATHOLOGY to the University of Agricultural Sciences, Bangalore, is a record of research work carried out by **Mr. K. PRAVEEN KUMAR**, under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.

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FEBRUARY , 1995


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INTRODUCTION

I. INTRODUCTION

Greengram (Vigna radiata (L.) Wilczek) is an important pulse crop grown principally for its protein rich edible seed. Due to its rapid growth and early maturity, it is adapted to multiple cropping systems in the drier and warmer climates of the tropics and sub-tropics.

In India, greengram occupies an area of 2537 thousand hectares with a production of 1305.5 thousand tonnes, and it is cultivated in about 350 thousand hectares in Karnataka producing nearly 162 thousand tonnes. (Anon., 1993).

Powdery mildew caused by Erysiphe polygoni D.C. is an important disease of Greengram. An yield loss of 21 percent due to powdery mildew was reported by Quebral and Lantican (1969).

Powdery mildew is severe at temperatures of around 26⁰ C and high relative humidity (80 - 88 percent) (Soria and Quebral, 1973).

Several effective fungicides have been recommended by various workers (Kotasthane and Agrawal, 1978, Raul et. al., 1986), but use of fungicides may not be economical.

Therefore a search for greengram genotypes with resistance to powdery mildew, particularly durable resistance is very useful.

The present work was undertaken to evaluate a collection of greengram genotypes for partial resistance and to characterize the components of partial resistance.

The objectives of the study were,

1. to assess greengram genotypes for partial resistance to powdery mildew.
2. to study the components of partial resistance.
3. to study the early events of infection process.
4. to estimate the yield loss due to powdery mildew.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Powdery mildew incited by Erysiphe polygoni D.C. is a common foliar fungal disease of greengram. The disease is severe in the cool dry months. Chemical control measures are not economical to farmers. Therefore, host resistance is an effective and economical means of reducing loss due to powdery mildew in greengram.

Pathogens vary greatly in the way and rate they multiply and spread. Resistance generally affects the multiplication of the pathogen rather than its spread. Several terms have been used to describe apparently different types of host reaction to disease. (Caldwell, 1968, Nelson 1973; Thurston, 1971). Vertical resistance directed against an individual race of the pathogen, reduces the initial inoculum 'X₀' and the horizontal resistance operating against all races of a pathogen reduces the infection rate 'r' according to Van der plank (1963).

Horizontal or polygenic resistance is popular as being more stable, due to the dynamic nature of the host pathogen relationship as against the genetic adaptation of the pathogen which overcomes the introduced vertical or major gene resistance.

Partial resistance is a form of incomplete resistance, characterized by a reduced rate of epidemic development

(Parlevliet, 1979). It is conditioned by a number of genes with small effects. (Asher and Thomas, 1983 Jones et al., 1982). It has been found that this type of resistance is effective for many years under the conditions in which the crop is cultivated. (Shaner, 1973a; Jones and Hayes, 1971). Newton, (1992), found that barley cultivar cv Golden Promise was partially resistant even after 32 inoculation cycles with the powdery mildew pathogen Erysiphe graminis f.sp. hordei.

Partial resistance includes phenomena such as slow mildewing (Shaner, 1973b), slow rusting (Kochman and Brown, 1976 Luke et al., 1972 Parlevliet, 1976 and Wilcoxson et al., 1974), moderate resistance (Heagle and Moore, 1970), field resistance (Guzman, 1964), r-reducing resistance (Parlevliet, 1979) and dilatory resistance (Browning et al., 1977). It is common in epidemics caused by polycyclic pathogens such as rusts and mildews.

Slow mildewing is expressed in the reduced infection of a plant by a fungus, late appearance of mildew and retarded development of the fungus. Slow mildewing has been described in barley against powdery mildew (Jones and Davies, 1985; Newton, 1992), cowpea against powdery mildew (Raju and Anil Kumar, 1990), soybean against powdery mildew (Mignuci and Lim, 1980). Similarly it has also been described as effective in wheat cultivar infected with powdery mildew

(Roberts and Caldwell, 1970 Griffey, et al., 1993). Slow rusting phenomenon has been described in wheat attacked by stem rust (Wilcoxson et al., 1974), cowpea against leaf rust (Chandrasekhar et al., 1989).

1. ASSESSMENT OF PARTIAL RESISTANCE

Resistance is often measured by assessing the disease symptoms with the assumption that they quantitatively reflect the growth of the pathogen in or on the host (Parlevliet, 1979). In the case of ectopathogens like powdery mildews and rusts it is relatively simple and the disease symptoms can be assessed visually. Rate - reducing resistant cultivars are identified by assessing the proportion and time of appearance of the disease, the less and late they become visible, higher will be their partial resistance (Parlevliet, 1980).

Jones and Davies (1985), assessed a collection of 133 genotypes of old European barleys and land varieties for the level of partial resistance to barley mildew. Thirty nine varieties were known to have relatively high level of partial resistance. Further, subjecting these to field nurseries over a period of three years, thirteen varieties with significantly less percentage of leaf area infected than the control variety Procter were identified.

Norgaard Knudsen et al., (1986), evaluated the partial resistance to powdery mildew in spring barley. The percent

leaf area covered by mildew was scored four to six times during the season. Seven of the ten varieties tested, possessed levels of partial resistance equal to Procter a known slow mildewer. Shaner, (1973a), evaluated six wheat cultivars to search for adult plant resistance, because of the short lived nature of the major gene resistance. During grain filling, mildew severity was substantially lower on Knox and it's progeny than on susceptible cultivars.

In a screening of several cultivars of wheat with adult plant resistance, Griffey et al., (1993), found that cultivars Massey, Red coat and Houser were better than Knox 62. Mignuci and Lim (1980), reported that soybean cultivars Clark, Cloud, Cutler, Hawkeye, Mukden and Custer as having adult plant resistance to powdery mildew. Twenty cowpea germplasm lines were assessed under glasshouse conditions for partial resistance to a field population of powdery mildew fungus, Erysiphe polygoni. The disease severity was monitored twice a week using standard area diagrams. Genotypes APC-68, 585, 809 and 780 were found to exhibit partial resistance with mildew cover on them never exceeding ten percent of the leaf area as compared to 61.6 percent mildew cover on the susceptible APC-146. (Raju and Anil Kumar, 1990).

Partial resistance has been described in several crops against a variety of diseases. Seven cultivars of winter

wheat were screened in field trials to determine their levels of slow rusting ability towards brown rust. Cultivar Bouquet was most resistant, while Aton and Maris freeman were reported as slow rusters (Poyntz and Hyde, 1985) Kapoor et al., (1986) followed stem rust development in 1978-79 on six wheat cultivars which were susceptible as seedlings and adults to race 122 of Puccinia graminis tritici. Rust severity was substantially lower on Sonalika wheat than on Agra local and Kharchia.

Yeh and Bonman, (1986) assessed six rice cultivars for partial resistance to Pyricularia oryzae. IR-36, Milyang-42 and Milyang-30 which showed relatively little disease were reported partially resistant. Their susceptible counterparts IR-50 Milyang-57 and Suwon 264 showed a rapid increase in disease. Estrada et al., (1990), reported that Indian cultivar IR-36, and Japonica cultivars Seomjin and Bonggwang were partially resistant to leaf and neck blast. Low neck blast incidence and therefore negligible yield losses were recorded in these cultivars.

Chandrasekhar et al., (1989), tested nine cowpea varieties against leaf rust. RC-19 and Guj-2 showed a highly resistant response. Varieties V-16, V-70 and V-118 indicated a slow rusting behaviour. Rate reducing resistance to Ascochyta blight in Chickpea cultivars ILC-482 and ILC-3279 was reported by Reddy and Singh (1993).

2. QUANTIFICATION OF PARTIAL RESISTANCE

The data obtained by measuring disease severity several times from the beginning to end of an epidemic is used to obtain the two epidemiological parameters, the infection rate and the area under the disease progress curve value.

2.1 APPARENT INFECTION RATE

The Logistic or the Gompertz model are used to derive the infection rate.

2.1.1 LOGISTIC INFECTION RATE

Vanderplank (1963) suggested the calculation of apparent infection rate 'r', to quantify the rate of disease development. The 'r' value has been used by plant pathologists to evaluate data on effectiveness of sanitation, fungicidal application, and cultivar resistance (Fry, 1978 Pennypacker et al., 1980 ~~and~~ Zadoks and Shein, 1979).

Shaner (1973a) suggested that Knox wheat with a lower infection rate 'r' than the two susceptible wheat cultivars, Vermillion and Riley 67 can provide a source for the practical and stable control of powdery mildew. Mackenzie (1976) compared two stem rust susceptible spring wheat cultivars (Pitic 62 and Penjacuo 62) to the slow rusting cultivar Bonza 55 for their gross epidemiological attributes (i.e., reduced spread and rate of increase)

which might characterize slow rusting. Analysis of physically isolated stem rust epidemics indicated that reduced spread and lessened rates of increase on Bonza 55 relative to the susceptible varieties characterized slow rusting.

Statler et al. (1977) recorded the general resistance displayed by three hard red spring wheat cultivars to leaf rust. The logit analysis of percent disease severity was computed and the apparent infection rate 'r' compared. Slow rusting cultivars consistently exhibited lower apparent infection rate as compared to the fast rusting Thatcher. Kapoor et al. (1986) found infection rates 'r' calculated from logit analysis to be lower on wheat cultivar Sonalika than on other wheat cultivars namely Agra local, Kharchia, C-306 and K-68. Sharma et al. (1986) reported that slow rusters had a lower infection rate when the slow rusting ability of fourteen wheat varieties was studied in the adult plant stage against Puccinia striiformis.

Berger and Luke (1979) while studying spatial and temporal spread of oat crown rust, plotted disease progress curves of three varieties, employing logit transformed values of disease severity recorded during various intervals and found significant differences in average apparent

infection rate (r) among varieties. Villareal et al (1980) successfully employed logit transformation of blast severity on rice cultivars to critically evaluate the cultivars for sources of rate reducing resistance. They assessed sixteen rice cultivars by inoculating with a highly virulent and stable isolate of Pyricularia oryzae and found some of the 16 cultivars showing slow blasting tendencies as evidenced by reduced r -values (0.02 - 0.12) as compared to three check cultivars ($r=0.20$ - 0.23). They concluded that the prospects for developing slow blasting rice cultivars was promising. Similarly Reddy and Singh (1993), reported the chickpea cultivar ILC-482 and ILC-3279 as having rate-reducing resistance to *Ascochyta* blight on the basis of apparent infection rate ' r ', which was $r=0.16$ - 0.29 and $r=0.03$ - 0.23 respectively as against $r = 0.24$ - 0.68 in the susceptible ILC464.

The rate of disease increase ' r ' of leaf rust of cowpea was calculated on the basis of leaf area covered and pustule density and it was found that varieties BG-329, Covu-385, GC-28, GC-104, GC-82-7 and DPI-1243 recorded low ' r ' values (Shoba Cherian, 1993).

2.1.2 GOMPERTZ INFECTION RATE

Berger (1981) used the Gompertz model developed by the British mathematician B.Gompertz in comparison with the logistic model to analyse 113 plant disease progress

curves of 9 patho-systems. He found that this model provided a better statistical fit than the logistic model for all the disease progress curves. It avoided the curvilinearity associated with logit transformed values. The erroneous interpretation of epidemic parameters resulting from logistic transformation of asymmetrical disease progress curves with skewed distribution of values was overcome by this model. In addition, estimation of epidemic rate, projection of future disease severity and determination of initial disease were more accurate with the Gompertz model.

Luke and Berger (1982) studied slow rusting in oats compared with the logistic and Gompertz models. They found that, when the disease severity was low, small increases in disease caused great increases in the logistic rate (r) compared to changes in the Gompertz rate (k). Logistic transformation caused considerable variation in rusting rates for individual cultivars proving less consistent than the Gompertz transformation in detecting degrees of slow rusting.

Poyntz and Hyde (1985) studied slow rusting of wheat to Puccinia recondita. Gompertz transformation of the disease progress data allowed better comparison of cultivars than the logistic transformation.

Chandrasekhar et al. (1988) subjected the weekly observation of rust severity on cowpea varieties recorded as uredinia per cm² to Logistic and Gompertz transformations for computation of the infection rate. Gompertz model was found to be more suitable because of the lower variation in infection rate, lower standard errors of estimate and higher correlation coefficients achieved by it in comparison with the logistic model.

Raju et al. (1991) identified V-905, V-269, V-276, V-282 and V-385 as slow mildewing cowpea cultivars by employing Gompertz transformation. Shoba Cherian (1993) also found that Gompertz conversion projected the reaction of cowpea genotypes against leaf rust in a better way than the logistic conversion.

2.1.3 AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC)

Evaluations of partial resistance are most precise if several disease recordings are made during the development of the epidemic and disease progress curves are constructed. When disease progress curves are to be used, disease severity should be judged atleast at the beginning and at the termination of the epidemic, but several additional evaluations provide more realistic curves. Data from the disease progress curves may be reduced to a single statistic to facilitate data analysis by means of area under the disease progress curve (AUDPC) values (Wilcoxson, 1986).

The area under the disease progress curve (AUDPC) value was used to estimate slow rusting resistance in eight barley cultivars. The AUDPC value distinctly separated the eight cultivars for their slow rusting resistance to Puccinia hordei (Andres and Wilcoxson, 1986). Pretorius and Wilcoxson (1986) studied slow rusting in barley (Puccinia hordei) by converting the leaf rust severity data to area under the disease progress curve.

Wilson and Shaner (1987) found rust severities and area under disease progress curve of resistant varieties to be low and correlated with each other in the evaluation of six triticales for slow leaf rusting. Yashitola and Sharma (1991) evaluated wheat cultivars for slow rusting against leaf rust (Puccinia recondita f.sp. tritici). AUDPC clearly separated out the slow rusters. Fast rusting Sonalika and Lal Bahadur had AUDPC values of 928 and 1435 in comparison to 81.75 and 179.00 for the slow rusters HD-2278 and HD-2264. It was 345.25 and 529.00 in the medium rusters UP-262 and HUW-206 respectively. Kapoor et al. (1986) recorded lower values of AUDPC for slow stem rusting wheat cultivars in a field evaluation.

Yeh and Bonman (1986) employed area under disease progress curves, to assess partial resistance to Pyricularia Oryzae in six rice cultivars. They found IR-36, Milyang 42 and Milyang 30 to possess partial resistance.

Raju and AnilKumar (1990) found AUDPC values based on severity clearly reflecting the resistance level in the twenty cowpea lines against powdery mildew fungus, Erysiphe polygoni. Highly susceptible APC-146 had a AUDPC value of 85.7 while slow mildewers APC nos. 68, 585, 780 and 809 had values 18.6, 19.0 11.6 and 16.0 respectively. Raju et al. (1991) recorded the powdery mildew severity of twenty cowpea cultivars as AUDPC and infection rate using Gompertz transformation. Slow mildewers V-105, V-269, V-276, V-282 and V-385 had low values of AUDPC and infection rate compared to the susceptible cultivars V-36 and TVX-1836-9E. Regression analysis of the relationship between AUDPC and infection rate, incidence and AUDPC and incidence and infection rate were non-significant for the slope coefficients of infection rate but significant for AUDPC. Thus AUDPC was reported as a more robust disease parameter than infection rate. AUDPC values were helpful in clearly distinguishing slow rusting cowpea genotypes (Shoba Cherian, 1993). Steffenson and Webster (1992), studied quantitative resistance in Barley to P. recondita the net blotch pathogen using AUDPC. They found that the susceptible check Kombar exhibited high AUDPC values while Tifang the resistant check exhibited lower AUDPC values. Based on this, they concluded that cultivars Atlas, Beechar. Hazera, Cape and VC 603 to have different levels of quantitative resistance.

Apparent infection rate and AUDPC have also been calculated by employing the disease incidence (number of plants infected per unit area or number of leaves infected per plant or severity (such as percent leaf area or plant area affected, number of lesions or pustules per cm².) data, by various workers (Luke et al., 1972 Statler et al., 1977 Headrick and Pataky, 1987 Chandrasekhar et al., 1988 Raju et al., 1991).

3. COMPONENTS OF R-REDUCING RESISTANCE

The rate 'r' reduces when the rate of spore production decreases resulting in fewer lesions which start to produce spores later at a lower rate (Parlevliet, 1979). these components of partial resistance being heritable traits could be used to develop lines that possess a combination of such characters (Skovmand et al., 1978).

3.1 COLONY SIZE

Colony size is an important component of partial resistance. Infact, the colony size may be an indirect reflection of spore production (Hyde and Elahinia, 1990).

Johnson and Wilcoxson (1978) have reported smaller uredia in slow rusting barleys MN-7572, MN-7541, MN-9062 and Rogers as compared to their fast rusting counterparts. Arntzen and Parlevliet (1986) studied the development of barley leaf rust Puccinia hordei infections in three barley

genotypes that varied from extremely susceptible (Akka) to an extreme level of partial resistance (17-5-16). The investigations revealed that Akka had the largest colonies, 17-5-16 the smallest with Vada at an intermediate position.

Shaner (1973 b) found, that colony size was less on the slow mildewing Knox wheat cultivar than on the susceptible Vermillion. Ohm and Shaner (1976) have reported pustule size as an important component of slow leaf rusting in wheat. Slow rusters Suwon 85 and P-6028 had a pustule size four to six times smaller than that of fast rusters Monon and Suwon 92. Yeh and Bonman (1986), reported that of the nine varieties of rice that were subjected to assessment of partial resistance against Pyricularia oryzae, it was observed that genotypes with high degree of partial resistance had smaller size lesions.

In the assessment of cowpea germplasm lines for slow mildewing, Raju and Anil Kumar (1990) found colony size to be an important component in identifying the resistant genotypes. Large differences between the rust pustule sizes of the susceptible cowpea cultivar C-152 and most of the promising lines were found by Shoba Cherian, (1993), who concluded that pustule size is an important component contributing to reduced disease level. Ashok Krishna and Mishra, (1989), reported colony size as a major component of partial resistance in slow mildewing of peas.

3.2 COLONY NUMBERS

Number of colonies or lesions, especially the sporulating ones, per leaf or per unit area many a times reflect the extent of partial resistance. Usually there is a negative correlation between number of colonies or sporulating colonies to partial resistance.

Ohm and Shaner (1976) reported number of pustules per square centimeter of leaf area as an important component of slow leaf rusting in wheat. Partially resistant Suwon 85 consistently developed fewer pustules per square centimeter of leaf area compared to fast rusters Monon and Suwon 92. Johnson and Wilcoxson (1978) have also reported pustule density as a major component in slow rusting of barleys.

Yeh and Bonman (1986), assessed the partial resistance of rice genotypes to Pyricularia oryzae. The cultivars Milyang 42 and IR-36 possessing high degree of partial resistance had 102 and 133 lesions per 100 cm² on partially extended sixth leaf as against 344 lesions/ 100 cm² in case of susceptible cultivar IR-50. Similarly in another study on partial resistance to blast disease, Kamel et al. (1989), found that highest number of lesions occurred on Richo and Giza 159, while very low numbers were recorded on the partial resistant cultivars Goza-1394-10-1.

3.3 SPORULATION

The extent of sporulation (SP) per lesion or per unit area reflects the resistance levels of a host genotype. Generally, varieties on which the pathogen has low sporulation capacity, are known to be more resistant. Sporulation is expressed in various ways, such as SP per unit leaf area, SP per lesion or SP per unit area of sporulating surface (Parlevliet, 1979). Reduced infectability and inoculum production were studied as main factors of slow mildewing in Knox wheat by Shaner (1973b). The number of conidial chains per unit area of colony was less on Knox than on Vermillion. Converting this to sporulation index, a measure of spore producing capacity of a colony, it was found that mildew spread only one third as fast on Knox as on Vermillion. Shaner et al. (1978) reported that fast leaf rusting wheat cultivars Monon and Suwon 92 produced more Urediniospores per day per uredinium, when compared to the partially resistant Suwon 85 and P-6028. Poyntz and Hyde (1987) determined the components of partial resistance contributing to slow rusting in wheat cultivars. Cultivars Aton, Bouquet, Cappelle - Desprez and Maris Freeman produced less urediniospores per unit area than the control CV.Armada.

Fallahti Rastgar (1988) also reported that sporulation capacity as an important component of partial resistance to

Puccinia striiformis in wheat. Yeh and Bonman (1986) found that among the six rice cultivars evaluated for partial resistance to Pyricularia oryzae the three genotypes Milyang 42, IR-36 and Milyang 30 that exhibited partial resistance had smaller lesions with lower sporulation capacity. Similar results were reported by Kamel et al. (1989).

Raju and Anilkumar (1990) reported conidia per colony as a component of slow mildewing in cowpea cultivars. Conidial suspension from the leaflets of the twenty germplasm lines were examined on a haemocytometer to assess conidia per colony. Fast mildewer APC-146 had four times more conidia than the partially resistant cultivars APC-68, APC-780 and APC-809. Sporulation per uredium was helpful in identifying partially resistant cowpea genotypes. The promising genotypes produced less than 500 spores per uredium as compared to 6395 spores per uredenium in the susceptible C-152 (Shoba Cherian, 1993).

4. EFFECT OF ENVIRONMENT ON DISEASE SEVERITY

Variations in the incidence of a disease is known to exist during different years and due to different dates of sowing within a season, possibly as a function of changing environmental conditions in the field. Various workers have also studied the effect of different dates of sowing on the severity of a disease.

Soria and Quebral (1973), studied the incidence of powdery mildew on greengram and reported that incidence was highest in January 1970, when the monthly mean of temperature, relative humidity, wind velocity and solar radiation and rainfall were 25.6 Deg.C, 85 %, 1.8mph, 9976 g/cal.Sq.cm days and 1.61 inches respectively. They concluded that greengram should be planted at a time when vegetative growth does not coincide with environmental conditions favourable for powdery mildew.

The resistance mechanisms in greengram against powdery mildew was found to be affected by daylength and the disease was found to be serious under short day conditions (Anon,1981). Hsieh et al.(1988) found that the powdery mildew on greengram was more severe in the crop grown in autumn than those planted in spring. They also found that the disease was directly and indirectly influenced by environmental factors. Similarly Moghe and Utikar (1981) reported that the field incidence of powdery mildew in greengram was minimum on crops sown in mid August and maximum on those sown in late July. Raju et al (1991), reported significant effects due to season of planting on the AUDPC values of powdery mildew epidemics of cowpea genotypes. In addition to these the micro climate of the crop also plays an important role in the development of a powdery mildew epidemic. (Aust and V.Hoyningen Huene, 1986 ; Newton, 1992).

5. EARLY EVENTS OF INFECTION

Several alternative events during primary invasion by Erysiphe determine the success of the host pathogen relationship. They are the germination of conidia, formation of appresoria and penetration peg, formation of haustoria and the formation of papilla at the encounter site which may impede further progress. (Johnson et al., 1979). Russel et al (1975) suggested that the proportion of Erysiphe graminis conidia which germinates on barley leaves within 2-3 days of inoculation can be affected by the genotype of the host plant. They found significantly more germination of conidia on seedlings of Procter than those of Maris mink with isolate G9A. Further they concluded that since resistance to germination of E.graminis conidia is a component of inherited resistance to powdery mildew of barley, it may contribute to disease resistance in the field. Similarly Scholze and Rover, (1989) reported that percentage germination of Erysiphe graminis f.sp. hordei conidia increased with increased susceptibility of host barley plants.

However Douglas et al., (1984) and Carver and Adaigbe, (1990), did not find any significant difference in the germination of conidia on susceptible and resistant genotypes.

Carver and Carr, (1977) noted Erysiphe sporelings on oats were less successful in penetrating mature leaves of adult plant resistant cultivar Maldwyn than that of a susceptible cultivar. From the penetration peg stage onward, papilla were almost invariably found at the penetration site. They stated that resistance to primary penetration appeared to be a component of adult plant resistance, and that papilla formation was implicated as a defense mechanism. Douglas et al., (1984) also found a correlation between papilla formation and adult plant resistance in Maldwyn, which had more papillae and supported fewer haustoria than the susceptible cultivar Mariner. Certain Barley and Oat lines support more frequent penetration at stomatal regions than in regions more distant from stomata, which indicated that adult plant resistant plants might show a reduction in the vulnerability of the stomatal region relative to susceptible plants. (Johnson et al 1979 Carver and Carr, 1977).

Douglas et al., (1984) observed that the resistance of Maldwyn was associated with a decrease in percentage of conidia which produced a germ tube at least as long as the width. Similarly Carver and Adaiibe, (1990) found that on Maldwyn (adult plant resistant cultivar) a slightly lower percentage of germlings formed an appresorial germtube than on Selma (susceptible cultivar). They also found that on

Maldwyn, a smaller percentage of primary germ tubes were associated with localized host cell responses, than on selma and that this might indicate that primary germ tube infection pegs were unable to breach the host cell walls of Maldwyn as deeply or as easily as those of Selma.

Hite et al. (1977) reported that leaves of the Adult plant resistant oat cultivar Dal supported only moderate mycelial development and sparse sporulation whereas the leaves of the susceptible cultivar Mariner supported heavy mycelial growth and abundant sporulation.

6. YIELD LOSS DUE TO POWDERY MILDEW AND CONTROL OF POWDERY MILDEW OF GREENGRAM

Powdery mildew reduced the yield of greengram upto 21 percent in the Phillipines when all the leaves were covered with Erysiphe polygoni colonies. (Quebral and Lantican, 1969). Upto 40 percent loss due to powdery mildew was recorded in Taiwan (Anon., 1984).

In India, Gupta et al (1975), found that controlling powdery mildew of greengram to the extent of 98.5 percent resulted in a yield increase to the extent of 27.59 percent. Moghe et al (1982), found that complete control of greengram powdery mildew increased yields upto 172.59 percent. Reduction in shoot length, root length, nodulation and plant growth in addition to reduction in the protein content of seeds of blackgram with increase in intensity and infection

of powdery mildew was reported by Nawaz and Narayana swamy, (1983).

Kotasthane and Agrawal (1978), reported Bavistin (Carbendizim) as the most effective fungicide against control of powdery mildew of greengram. Similarly Carbendizim at 0.1 % was found to be the best fungicide to control powdey mildew of blackgram (Krishnamohan et al., 1986) Cowpea (Singh and Anil Kumar, 1986).

Several other fungicides like Sulfur dust (Moghe et al., 1982) Wetsulf (Agrawal and Philip, 1983) Karathane (Nawaz and Narayanaswamy, 1983) Calixin (Raul et al., 1986) and Thiophanate-methyl (Elazegui and Mew, 1987) have been reported to be effective in control of greengram powdery mildew.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The experiments were conducted at the Gandhi Krishi Vignana Kendra and Hebbal campuses of the University of Agricultural Sciences, Bangalore, during the 1992-1993 and 1993-1994, Rabi/summer seasons. The details of the experiments are presented in Table 1.

1. GREENGRAM GENOTYPES

Thirty eight greengram genotypes from the germplasm collection maintained at the All India Coordinated Research Project on Improvement of Pulses, UAS , GKVK were used. The details are given in Table 2.

2. THE PATHOGEN

Greengram powdery mildew fungus Erysiphe polygoni D.C. was the pathogen against which the study was carried out. To isolate the partial resistance material the screening was done under the field as well as under controlled conditions in both rabi / summer seasons.

3. EXPERIMENTS FOR ASSESSMENT OF PARTIAL MILDEW RESISTANCE

3.1 FIELD LAYOUT

Thirty eight genotypes were sown on November 9, 1992, in two replications in single line of four metres length with a spacing of 30 cms between rows, in a randomized complete block design. All the recommended package of practices (Anon., 1989) were followed, in raising the crop with protective irrigations.

TABLE 1. DETAILS OF EXPERIMENTS CONDUCTED TO EVALUATE GREENGRAM GENOTYPES FOR PARTIAL RESISTANCE TO MILDW

EXPT. NO.	LOCATION	DATE OF SOWING	NO. OF BENTYPES	SOWN	OBSERVATIONS RECORDED (DAYS AFTER SOWING (DAS))	TYPE OF OBSERVATIONS RECORDED
I	Field	09.11.1992	38	39,45,48,52,59,63,69	Leaf Area Covered (LAC)	
II	Cage house	14.11.1992	38	32,37,42,45,49,53	Leaf Area Covered (LAC)	
III	Glass house	17.07.1993	16	27,31,37,42,49,55,60	Leaf Area Covered, colony size; conidia per colony, conidia per unit area	
IV	Cage house	07.09.1993	16	40,44,49,55,59	Leaf Area Covered, colony size; conidia per colony, conidia per unit area	

TABLE 2. LIST OF GENOTYPES

SL NO	GENOTYPE	SL NO	GENOTYPE
1	Barabanki	20	MUM-3
2	GM-84-26	21	NDM-53
3	GM-85-33	22	PDM-219
4	GM-85-68	23	PDM-84-143
5	GM-87-28	24	PM-89117
6	K-851	25	PUSA-105
7	LGG-450	26	PUSA-9272
8	MGG-221	27	RKM-816b
9	MGG-335	28	RMG-266
10	ML-5	29	SG-1
11	ML-131	30	SML-100
12	ML-267	31	SML-119
13	ML-337	32	SMS-1340
14	ML-408	33	TARM-1
15	ML-434	34	TARM-18
16	ML-459	35	UPM-89-9
17	ML-505	36	VGG-7
18	ML-537	37	WGG-2
19	ML-5067	38	WGG-35

3.2 SCREENING FOR POWDERY MILDEW RESISTANCE

Screening for resistant material was done under natural conditions during rabi 1992-93. Powdery mildew epiphytotic was developed from the natural inoculum. Observations were recorded for first appearance of disease. Following the first appearance of powdery mildew, the plants were scored for powdery mildew severity by recording the percent leaf area covered by the disease, through visual estimation, using a rating scale of 0 to 100 percent (James, 1971). The severity was recorded at an interval of 3-6 days during the epiphytotic by selecting three leaves per plant on four plants from each replication on a random basis.

4. COMPUTATION OF INFECTION RATE BY USING LOGISTIC AND GOMPERTZ MODELS

The Epidemiological concept, infection rate was calculated from the data generated. The infection rate expressed as Logistic and Gompertz function 'r' and 'k' respectively were worked out and compared using the formulae given by Vanderplank (1963) for 'r' and Berger (1981) for 'k'. Accordingly,

$$r = \frac{\text{logit } Y_2 - \text{logit } Y_1}{t_2 - t_1}$$

where r = logistic infection rate

Y1 = Initial proportion of disease at time t1

Y2 = Proportion of disease at time t2

$$k = \frac{\text{Gompit } Y_2 - \text{Gompit } Y_1}{t_2 - t_1}$$

where k = Gompertz infection rate

Y_1 = Initial proportion of disease at time t_1

Y_2 = Proportion of disease at time t_2

5. CALCULATION OF AREA UNDER DISEASE PROGRESS CURVE (AUDPC)

The Area Under Disease Progress Curve (AUDPC) values were calculated for each entry based on the leaf area covered by the pathogen. The calculation was done by employing the formula proposed by Wilcoxson et al (1975).

Accordingly,

$$A = \sum_{i=1}^K 1/2 (S_i + S_{i-1})$$

where A = Area Under Disease Progress Curve (AUDPC) values.

S_i = Powdery mildew severity at the end of week i .

K = Number of successive evaluations for mildew.

6. CAGE HOUSE AND GLASS HOUSE EXPERIMENTS

The 38 genotypes were tested under cage house conditions. The seeds were sown on November 14, 1992. The plants were raised in polythene bags of 10" x 7" size. Each genotype was replicated four times. Twenty day old seedlings were artificially inoculated by spraying a conidial suspension in water, of fresh powdery mildew, collected from greengram plants in the field. Observations were recorded

for initiation of infection and further development at an interval of 3 - 6 days. Infection rates, 'r' and 'k' and AUDPC values were also calculated.

Based on the results of experiments I and II, 16 genotypes consisting of the best performing ones (Low powdery mildew severities) and three of the more susceptible one were selected and sown in glass house (Experiment III) on July 17, 1993, in polythene bags of 10" x 7" size. Four replications were maintained. The same 16 genotypes, were tested again in the cage house (Experiment IV) by following the same procedure as explained in the earlier experiment. In both these experiments Twenty day old seedlings were artificially inoculated and the disease was scored by following the scale explained in the earlier experiment. Further, the colony size, conidia per colony, and conidia per unit area were recorded. The area of the individual colony was calculated by using a scale to measure the radius and obtaining the area by using the formula, $A = \pi r^2$

where A Area of the colony in Sq.mm

π • Constant (3.14)

r • radius (mm)

The number of conidia per colony was calculated by placing individual colonies in vials containing a known amount of water and a drop of Tween 20. The vials were

vigorously shaken to dislodge the conidia and then counted on a haemocytometer, using the formula,

$$\frac{\text{No. of spores} \times 2000 \times \text{Quantity of water taken}}{\text{No. of pustules}}$$

The number of conidia per colony was divided by the colony size to obtain conidia per Sq.mm

7. EARLY EVENTS OF INFECTION

Based on the resistance reaction, three genotypes namely NDM-53 (Slow mildew genotype) GM-87-28 (moderately resistant) and Barabanki (highly susceptible), were selected for studying the early events of infection. Twelve mm leaf discs were cut and placed in Petri dishes containing 0.5 per cent water agar, which was amended with 40 ppm benzi midazole. These were dusted uniformly with fresh powdery mildew conidia collected from infected greengram plants in the field. They were incubated at room temperature, and exposed to alternating light and dark periods of 16 hours and 8 hours respectively. Two leaf discs per genotype were sampled at 6 hours intervals, for a total of 72 hours and they were fixed in a 3 : 1 solution of absolute alcohol - glacial acetic acid mixture, in order to fix and decolorize the discs. The discs were then stained with lactophenol cotton blue and observed under microscope for the early events of infection process, like number of

conidia germinated, formation of appressoria, growth of secondary mycelia. The microscopic photographs were taken for confirmation.

8. EFFECT OF ENVIRONMENTAL FACTORS ON POWDERY MILDEW DEVELOPMENT

The data obtained from the screening experiments in the field and cage house experiments were correlated with weather factors namely temperature, relative humidity and rainfall.

9. ESTIMATION OF YIELD LOSS DUE TO POWDERY MILDEW

Three genotypes, NDM - 53 (slow mildewing type) Barabanki (highly susceptible) and PS - 16 (cultivated variety) were selected for estimating the yield loss. They were sown on August 11, 1993 in polythene bags (10" x 7") and maintained in the cage house. Each of this genotype was given four treatments namely, No spray one spray with carbendizim (Bavistin) @ 0.1 per cent at 20 days after sowing (DAS) two sprays at 20 and 40 DAS and three sprays at 20, 40 and 60 DAS. Four replications were maintained for all treatments. The seedlings were artificially inoculated at 15 days after sowing, to ensure the inoculum for the development of the disease. Observations were recorded for percent leaf area affected on the day of the third spray and also at the time of harvest. Further, the total number of leaves produced, number of leaves retained at harvest,

number of pods per plant, pod weight, seed weight, number of mature and immature seeds and germination percentage of seeds were recorded.

10. STATISTICAL ANALYSIS

The data were analysed following the techniques given in "Design and Analysis of field experiments" by Sundaraj et al.(1972), after suitable transformations wherever necessary. The least significant difference (LSD) or critical difference (CD) values were worked out wherever F was significant.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

A set of thirty eight greengram genotypes available at the All India Co-ordinated Research Project on Improvement of Pulses, University of Agricultural Sciences, Bangalore, were assessed and quantified for their reaction to powdery mildew. These genotypes were sown under field conditions in replicated trials on November 9th, 1992 and the same genotypes were raised in cage house in polythene bags on November 14th, 1992 as explained in Material and Methods. Based on the results of these two experiments, sixteen genotypes consisting of some of the best performing, moderately susceptible and most susceptible ones were selected and sown in polythene bags in a glasshouse on July 17th, 1993. Further, the sixteen genotypes were sown in cage house on September 7th, 1993 to test the development and reaction against powdery mildew. In all these experiments the percent leaf area covered (LAC) by the powdery mildew was assessed at an interval of three to six days, during the epiphytotic. The epidemiological parameters namely Area Under Disease Progress Curve (AUDPC) values and infection rate were calculated in all the above experiments to measure or quantify the mildew resistance. In the experiments III and IV the components of powdery mildew resistance namely, Colony size, number of conidia per Sq.mm were recorded.

1. POWDERY MILDEW PROGRESS

1.1 Field experiment

Powdery mildew was first detected on several genotypes on the 39th day after sowing (DAS). On the first day of screening (39th DAS), highest leaf area covered (LAC) was observed in K-851 (1.42%) and ML-5 (1.25%) and least on GM-87-28 (0.02 %), SML-100 (0.03 %). On most of the genotypes LAC did not exceed one percent. At the half way stage i.e, on the 55th DAS, maximum LAC was observed on K-851 (48.97 %) followed by LGG-450 (35.28 %) GM-84-26 (31.12 %) while least disease was noticed on UPM-89-9 (2.67 %), GM-87-28 (2.86 %), SML-119 (3.11 %), Tarm-18 (3.31 %) and SML-100 (3.62 %).

The extent of leaf area covered by mildew on the day of terminal screening (69 DAS) was maximum on Barabanki (77.36 %), followed by ML-5067 (73.89 %), MGG-221 (72.36 %), VGG-7 (69.53 %), GM-85-68 (67.37 %). Least disease at terminal screening was observed on genotypes NDM-53 (19.11 %), UPM-89-9 (30.42 %) and SG-1 (32.22 %). [Table 3].

1.2 Cagehouse experiment

Powdery mildew appeared earlier than in the first experiment i.e, at 32 DAS. On this day, maximum disease intensity (LAC) was observed on SMS-1340 (2.50 %), RMG-266 (2.38 %) and WGG-35 (1.75 %). The LAC was minimum on

TABLE 3. PERCENT LEAF AREA COVERED (LAC) BY MILDEW ON GREENGRAM GENOTYPES SOWN IN FIELD ON NOVEMBER 9, 1992

SL NO	GENOTYPE	AGE OF CROP IN DAYS									
		39	45	48	52	55	59	63	69		
1	Barabanki	0.06 (0.7441)	1.42 (1.3838)	1.97 (1.5716)	5.09 (2.3600)	16.96 (4.0357)	50.28 (7.1252)	45.00 (6.7271)	77.36 (8.8224)		
2	GM-84-26	1.09 (1.2566)	6.86 (2.6851)	10.39 (3.2292)	22.67 (4.8384)	31.12 (5.5774)	45.56 (6.7861)	50.14 (7.0894)	60.97 (7.8396)		
3	GM-85-33	0.14 (0.7951)	1.78 (1.4856)	3.36 (1.7867)	4.50 (2.2571)	5.34 (2.2571)	8.97 (3.0098)	11.57 (3.4727)	46.81 (6.8584)		
4	GM-85-68	0.03 (0.7277)	0.86 (1.1646)	1.64 (1.4339)	2.92 (1.7388)	6.53 (2.6305)	29.67 (5.4849)	42.87 (6.5845)	67.37 (8.2379)		
5	GM-87-28	0.02 (0.7176)	0.73 (1.1043)	1.40 (1.3827)	0.97 (1.2880)	2.86 (1.8311)	12.45 (3.4833)	21.00 (4.6368)	36.81 (6.1046)		
6	K-851	1.42 (1.0991)	5.17 (2.3773)	7.70 (2.7305)	20.81 (4.6142)	48.97 (6.9414)	57.00 (7.4970)	60.45 (7.7983)	51.53 (7.0871)		
7	L86-450	0.64 (1.0555)	3.61 (1.9864)	7.73 (2.8162)	20.39 (4.4937)	35.28 (5.9499)	69.31 (8.3537)	54.17 (7.3936)	56.11 (7.5236)		
8	M66-221	0.20 (0.8335)	1.08 (1.2427)	2.53 (1.7227)	10.19 (3.2586)	18.14 (4.2474)	60.28 (7.7735)	65.70 (8.1285)	72.36 (8.5019)		
9	M68-335	0.06 (0.7441)	0.36 (0.9272)	1.50 (1.4129)	3.31 (1.9184)	8.89 (3.0447)	28.97 (5.3814)	334.22 (5.7890)	38.09 (6.1353)		
10	ML-5	1.25 (1.0597)	0.78 (1.0967)	2.09 (1.6076)	4.94 (2.3224)	9.03 (3.0848)	27.22 (5.2452)	32.00 (5.6813)	45.00 (6.7206)		
11	ML-131	0.82 (1.1348)	0.83 (1.1523)	1.70 (1.4764)	8.19 (2.9451)	10.84 (3.3576)	36.72 (6.0967)	41.56 (6.4713)	42.78 (6.5413)		
12	ML-267	0.06 (0.7441)	0.70 (1.0931)	1.06 (1.2461)	2.92 (1.8383)	6.94 (2.7261)	24.70 (4.9741)	43.33 (6.6084)	45.69 (6.7446)		
13	ML-337	0.20 (0.8335)	1.00 (1.2071)	1.28 (1.2925)	4.08 (2.1197)	7.31 (2.7488)	32.23 (5.6732)	34.41 (5.7257)	51.70 (7.2226)		
14	ML-408	0.22 (0.8472)	0.78 (1.1272)	2.36 (1.6344)	4.28 (2.1780)	11.37 (3.4313)	30.67 (5.5824)	29.25 (5.4512)	51.11 (7.1781)		
15	ML-434	0.64 (1.0676)	1.78 (1.5044)	4.03 (2.1210)	10.56 (3.2919)	17.83 (4.2540)	60.28 (7.7863)	60.84 (7.8315)	64.17 (8.0414)		
16	ML-459	0.95 (1.2011)	4.00 (2.0993)	7.52 (2.7510)	15.70 (4.0242)	28.84 (5.4151)	50.20 (7.1200)	50.25 (7.0906)	50.42 (7.0912)		
17	ML-505	0.27 (0.8743)	1.28 (1.3342)	3.31 (1.9495)	10.87 (3.3644)	15.55 (3.9164)	32.97 (5.7789)	41.81 (6.4755)	34.28 (5.5869)		
18	ML-537	0.06 (0.7441)	0.61 (1.0450)	0.78 (1.1007)	2.81 (1.7200)	5.36 (2.3358)	30.03 (5.4997)	49.86 (6.9940)	58.62 (7.6707)		
19	ML-5067	0.36 (0.9216)	0.97 (1.2120)	3.00 (1.8047)	9.25 (3.0500)	14.14 (3.7830)	31.67 (5.6676)	50.78 (7.1605)	73.89 (8.6183)		
	SEM	0.0659	0.2485	0.3986	0.46	0.5934	0.6075	0.6438	0.6986		
	CD 5%	0.1828	0.6887	1.105	1.2752	1.6448	1.6839	1.7045	1.9143		

Figures in parenthesis are angular transformed values

TABLE 3. CONTINUED

SL NO	GENOTYPE	39	45	48	52	55	59	63	69
20	MUN-3	0.70 (1.0929)	4.70 (2.2778)	9.61 (3.1526)	13.00 (3.6737)	26.67 (5.1844)	52.22 (7.2536)	40.84 (6.3144)	58.33 (7.5229)
21	MUN-53	1.11 (1.0161)	1.25 (1.3158)	2.20 (1.6352)	5.78 (2.5048)	10.08 (3.2459)	28.44 (5.3439)	28.03 (5.2691)	19.11 (4.4229)
22	PM-219	0.17 (0.8185)	0.86 (1.1380)	3.00 (1.7672)	8.48 (2.6911)	12.28 (3.3482)	27.94 (5.2902)	34.20 (5.8556)	51.39 (7.1976)
23	PM-84-143	0.22 (0.8460)	0.86 (1.1429)	2.03 (1.5500)	6.00 (2.4926)	18.36 (4.2815)	40.56 (6.5046)	54.89 (7.4232)	39.43 (6.2221)
24	PM-89117	0.09 (0.7640)	1.42 (1.3672)	2.75 (1.7909)	6.89 (2.7183)	12.45 (3.4853)	35.17 (5.9073)	43.89 (6.6520)	60.70 (7.8219)
25	PUSA-105	0.15 (0.8058)	0.70 (1.0895)	1.00 (1.2007)	2.26 (1.6416)	4.72 (2.2764)	18.17 (4.2741)	30.22 (5.5396)	35.81 (5.9596)
26	PUSA-9272	0.13 (0.7981)	1.48 (1.3827)	1.95 (1.5534)	6.31 (2.5771)	12.14 (3.5161)	33.28 (5.8083)	49.03 (7.0327)	62.64 (7.9405)
27	RKN-9165	0.32 (0.9038)	1.36 (1.3467)	4.39 (2.1435)	6.14 (2.5539)	16.94 (4.1692)	40.34 (6.3798)	32.15 (5.6065)	65.00 (8.0930)
28	RMS-266	0.22 (0.8363)	3.59 (1.8637)	5.47 (2.2414)	17.25 (4.2124)	23.08 (4.8509)	44.59 (6.6936)	51.81 (7.1076)	49.72 (7.0510)
29	56-1	0.07 (0.7536)	0.45 (0.9615)	1.03 (1.2344)	2.81 (1.8122)	5.34 (2.3695)	23.39 (4.8855)	27.72 (5.2535)	32.22 (5.3932)
30	SML-100	0.03 (0.7277)	0.25 (0.8648)	0.50 (0.9899)	1.72 (1.4329)	3.62 (1.9746)	25.09 (4.7567)	35.70 (5.9986)	45.03 (6.7127)
31	SML-119	0.06 (0.7483)	1.25 (1.2504)	1.42 (1.3657)	7.03 (2.7850)	3.11 (1.8630)	24.48 (4.9381)	26.47 (5.0303)	44.00 (6.5028)
32	SMS-1340	0.28 (0.8810)	1.70 (1.4425)	1.36 (1.3635)	8.08 (2.9883)	12.75 (3.6102)	29.89 (5.5106)	37.64 (6.1505)	54.86 (7.4324)
33	TARM-1	0.17 (0.8148)	1.39 (1.3674)	2.22 (1.6471)	8.67 (3.0119)	15.70 (4.0236)	45.36 (6.7680)	53.47 (7.3341)	56.11 (7.5235)
34	TARM-18	0.22 (0.8485)	0.23 (0.8509)	0.78 (1.1087)	1.73 (1.4151)	3.31 (1.8420)	19.31 (4.3843)	34.04 (5.9243)	40.14 (6.3350)
35	UPM-89-9	0.07 (0.7981)	0.22 (0.8468)	0.20 (0.8335)	1.06 (1.2048)	2.67 (1.7790)	13.53 (3.7430)	12.06 (3.5263)	30.42 (5.5428)
36	V66-7	0.19 (0.8242)	1.53 (1.3096)	2.70 (1.7730)	6.28 (2.4973)	15.11 (3.9066)	38.17 (6.1975)	37.92 (6.1025)	69.53 (8.3538)
37	W66-2	0.18 (0.8195)	0.59 (1.0416)	2.19 (1.5925)	6.11 (2.5618)	13.36 (3.7044)	31.00 (5.5848)	33.55 (5.8341)	46.53 (6.8578)
38	W66-35	0.18 (0.8243)	1.67 (1.4671)	3.61 (2.0195)	5.16 (2.2490)	19.97 (4.4540)	35.00 (5.8620)	45.78 (6.7495)	66.94 (8.2100)
	SEM	0.0659	0.2485	0.3986	0.46	0.5934	0.6075	0.6438	0.6906
	CD 5%	0.1828	0.6807	1.105	1.2752	1.6448	1.6839	1.7845	1.9143

Figures in parenthesis are angular transformed values

GM-87-28 (0.14 %) and ML-267, ML-337, ML-459, ML-505 all of which recorded on LAC of 0.17 percent. However the powdery mildew did not appear until the 37th DAS on the genotypes ML-5, MUM-3, NDM-53, PDM-219, PUSA-105, PUSA-9272, SG-1 and UPM-89-9, when they recorded 0.75, 0.75, 1.92, 2.42, 1.96, 1.29, 1.62 and 0.96 percent LAC respectively. On the day of the last screening i.e, 53 DAS maximum LAC was recorded on SMS-1340 (61.88 %) ML-505 (61.58 %) Tarm-18 (57.5 %) ML-131 (55.21 %) while the genotypes GM-84-26, ML-337, PM-89117, RMG-266 recorded approximately 51 percent disease intensity. The genotypes Barabanki, GM-85-68, K-851, PDM-219, recorded an LAC between 46 and 49 percent. Least disease was observed on UPM-89-9 (16.67 %), MGG-335 (21.08 %), NDM-53 (26.25 %), SG-1 (28.04 %) and ML-434 (28.33 %) [Table 4].

In the above two experiments the genotypes Barabanki, ML-131, ML-505, ML-5067, MGG-221, VGG-7, GM-85-68, K-851, SMS-1340, Tarm-18 appeared to be among the most susceptible genotypes, while the genotypes UPM-89-9, SG-1 and NDM-53 showed presence of good amount of field resistance. Some of the genotypes like GM-87-28, ML-5, ML-267, PUSA-105, SML-100, SML-119 showed moderately susceptible reaction. On the basis of this 16 genotypes were selected for further testing.

TABLE 4. CONTINUED

SL NO	GENOTYPE	32	37	42	45	49	53
20	MUM-3	0.00 (0.7071)	0.75 (1.1149)	2.67 (1.7686)	4.00 (2.2995)	10.83 (3.3651)	31.04 (5.6095)
21	NAM-53	0.00 (0.7071)	1.92 (1.5275)	2.08 (1.5925)	6.04 (2.5406)	6.00 (2.5376)	26.25 (5.1710)
22	PDM-219	0.00 (0.7071)	2.42 (1.6897)	5.04 (2.3459)	0.29 (2.9483)	10.83 (3.3631)	48.13 (6.9691)
23	PDM-84-143	0.33 (0.9102)	1.34 (1.3511)	2.83 (1.8222)	6.25 (2.5964)	10.50 (3.3118)	43.17 (6.6065)
24	PR-89117	1.08 (1.2558)	7.25 (2.7785)	16.67 (4.1259)	21.92 (4.7043)	31.83 (5.6758)	51.56 (7.2091)
25	PUSA-105	0.00 (0.7071)	1.96 (1.5565)	6.63 (2.6681)	10.63 (3.3232)	14.42 (3.8422)	36.17 (6.0533)
26	PUSA-9272	0.00 (0.7071)	1.29 (1.3330)	3.17 (1.9046)	6.00 (2.5352)	9.71 (3.1867)	42.09 (6.5109)
27	RKM-9165	0.84 (1.1497)	1.14 (1.4779)	2.00 (1.5782)	5.42 (2.4252)	9.17 (3.1005)	29.17 (5.4405)
28	RMG-266	2.38 (1.6927)	6.29 (2.5309)	18.21 (4.2139)	24.42 (4.9141)	23.88 (4.8715)	51.04 (7.1767)
29	56-1	0.00 (0.7071)	1.62 (1.4476)	2.67 (1.7234)	0.04 (2.8827)	12.58 (3.5720)	28.04 (5.3318)
30	SIL-100	0.33 (0.9043)	2.62 (1.7541)	6.47 (2.6271)	14.13 (3.7799)	23.58 (4.8889)	37.92 (6.1759)
31	SIL-119	1.50 (1.3835)	4.56 (2.2334)	11.27 (3.3983)	14.83 (3.9102)	22.13 (4.7505)	34.96 (5.9321)
32	SMS-1340	2.50 (1.0544)	4.33 (2.1864)	22.63 (4.7835)	29.25 (5.4200)	43.92 (6.6542)	61.88 (7.0952)
33	TARM-1	0.29 (0.8879)	1.54 (1.4153)	5.54 (2.4298)	9.46 (3.8867)	15.17 (3.9151)	44.38 (6.6919)
34	TARM-10	0.75 (1.0574)	5.25 (2.3825)	9.00 (3.0767)	16.96 (4.1098)	17.70 (4.1747)	57.50 (7.6145)
35	UPM-89-9	0.00 (0.7071)	0.96 (1.2059)	1.25 (1.3206)	1.08 (1.2530)	1.75 (1.4916)	16.67 (4.1431)
36	V66-7	1.46 (1.3964)	2.91 (1.8370)	9.75 (3.1311)	21.42 (4.6525)	23.92 (4.9266)	38.37 (6.2278)
37	W66-2	0.50 (0.9886)	3.79 (2.0677)	6.29 (2.5983)	10.58 (3.2927)	14.83 (3.8401)	41.83 (6.4928)
38	W66-35	1.75 (1.4987)	4.17 (2.1453)	10.29 (3.2621)	11.75 (3.4756)	16.17 (4.0620)	29.30 (5.4646)
	SEN	0.0582	0.1263	0.2289	0.2803	0.2527	0.192
	CD 52	0.1613	0.3502	0.6345	0.777	0.7003	0.5322

Figures in parenthesis are angular transformed values

1.3 DISEASE PROGRESS ON SELECTED GENOTYPES

1.3.1 Glass house experiment

Sixteen selected genotypes which showed varying degrees of susceptibility and resistance in the previous experiments I and II were raised in glass house as explained in Material and Methods. Twenty day old seedlings were artificially inoculated with the pathogen, and the severity of the disease was monitored at regular intervals beginning from 27 DAS, when the powdery mildew first appeared. On the day of first observation the severity of the disease was less than one percent on all the genotypes. At 42 DAS, maximum LAC was observed on MGG-221 (28.97 %), PUSA-105 (25.67 %) and Barabanki (24.83 %) while least LAC was observed on SG-1 (7.03 %), Tarm-18 (5.42 %) and NDM-53 (10.11 %). On the day of terminal screening, disease severity was maximum on ML-131 (67.39 %) VGG-7 (63.63 %) Barabanki (59.01 %) SML-119 (58.07 %) and PUSA-105 (58.68 %) and minimum on NDM-53 (17.86%) SG-1 (30.12 %) Tarm-18 (30.78 %) [Table 5].

1.3.2 Cagehouse experiment

All the 16 genotypes were screened again in a cagehouse in a manner similar to the earlier experiment. The disease progress has been represented in Figure 1 and shown in Table 6. At 55 DAS maximum disease severity was recorded on MG-221 (53.61 %) followed by GM-87-28, ML-5 and VGG-7 all of which had nearly 36 percent LAC. Least per cent of leaf area

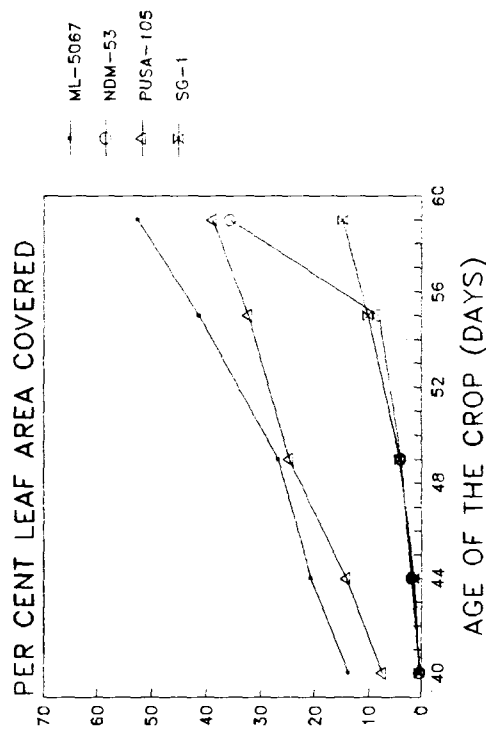
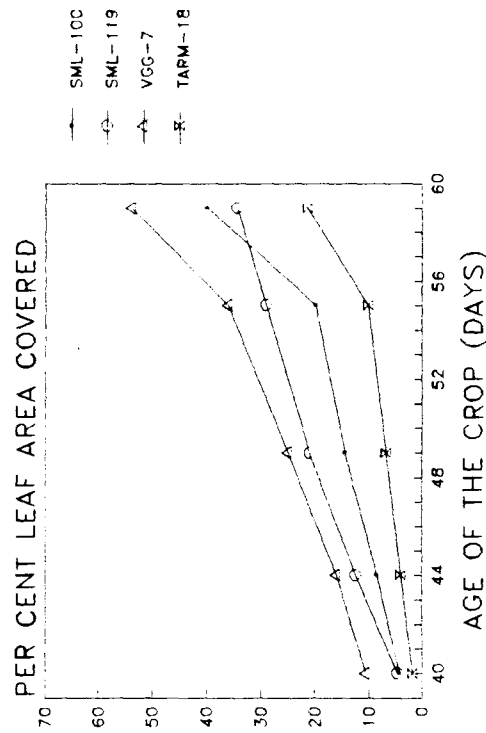
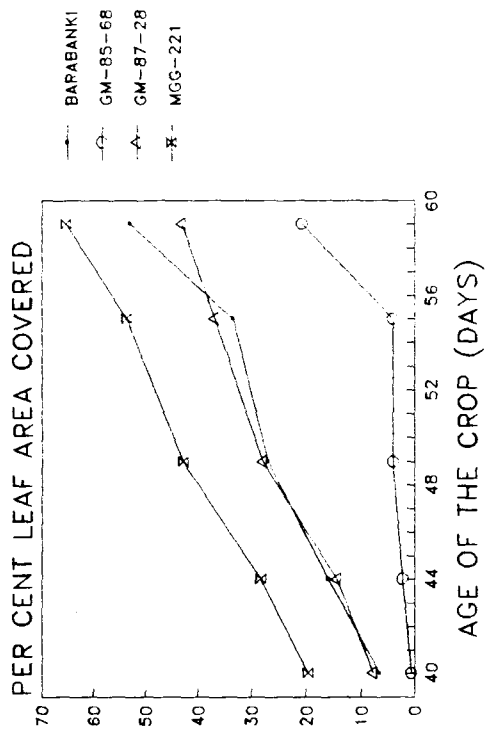
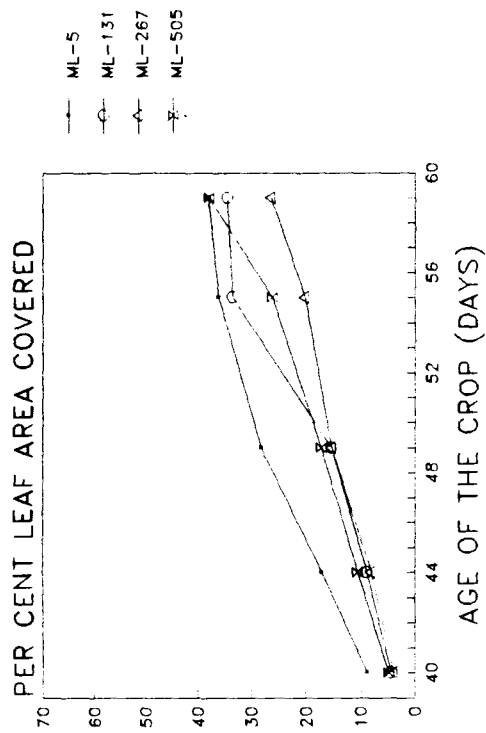


Fig.1. Progress of Powdery Mildew on selected genotypes in the experiment II

TABLE 6. PERCENT LEAF AREA COVERED (LAC) BY MILDEW ON SELECTED GREENGRAM GENOTYPES SOWN IN CAGE HOUSE ON SEPTEMBER 7, 1993

SL NO	GENOTYPE	AGE OF CROP IN DAYS						
		40	44	49	55	59		
1	Parabanki	6.52 (2.6478)	15.89 (4.8361)	26.98 (5.2356)	33.35 (5.6619)	52.92 (7.2972)		
2	GM-85-68	8.61 (1.8323)	2.25 (1.6411)	4.83 (2.1140)	4.88 (2.1323)	28.59 (4.5365)		
3	GM-87-28	7.76 (2.8487)	1.34 (3.7862)	27.89 (5.2885)	36.84 (5.9147)	42.92 (6.4888)		
4	MG8-221	19.57 (4.4648)	28.27 (5.3239)	42.78 (6.5197)	53.61 (7.2834)	65.28 (8.1826)		
5	ML-5	8.74 (3.8258)	17.86 (4.1518)	28.28 (5.993)	36.25 (6.8081)	38.22 (6.8795)		
6	ML-131	4.36 (2.1937)	8.92 (3.8573)	15.28 (3.9514)	33.56 (5.7965)	34.67 (5.8815)		
7	ML-267	3.86 (2.8636)	8.11 (2.9858)	15.33 (3.8684)	28.28 (4.3268)	26.48 (5.1828)		
8	ML-585	4.91 (2.3124)	18.58 (3.2976)	17.17 (4.1738)	26.25 (5.1895)	38.88 (6.8333)		
9	ML-5867	13.62 (3.7581)	28.64 (4.5612)	26.75 (5.1234)	41.28 (6.4219)	52.31 (7.2594)		
10	MDM-53	8.21 (8.8186)	1.86 (1.5242)	4.88 (2.1247)	8.86 (2.9162)	35.47 (5.9677)		
11	PUSA-185	7.42 (2.8819)	14.16 (3.8123)	24.78 (5.8188)	32.16 (5.7113)	38.66 (6.2534)		
12	SG-1	8.48 (8.9288)	1.39 (1.3546)	4.32 (2.1937)	18.12 (3.2554)	14.69 (3.8935)		
13	SML-188	4.42 (2.1299)	8.45 (2.8143)	14.39 (3.6511)	19.86 (4.2872)	39.89 (6.1259)		
14	SML-119	4.74 (2.2538)	12.28 (3.4769)	28.95 (4.5168)	29.88 (5.3177)	34.45 (5.7954)		
15	V88-7	18.6 (3.2911)	15.86 (4.8129)	25.88 (5.8138)	36.86 (5.9771)	53.75 (7.2815)		
16	TARM-18	1.86 (1.5279)	3.97 (2.1877)	6.73 (2.6683)	18.87 (3.2187)	21.35 (4.6838)		
	SEM	8.1871	8.2998	8.4211	8.5484	8.547		
	CD 5%	8.5185	8.8389	1.1673	1.498	1.5161		

Figures in parenthesis are angular transformed values

covered was observed on GM-85-68 (4.08 %) and NDM-53 (8.06%). There was a sharp increase in the disease severity of several genotypes between the 55th DAS and 59th DAS, i.e, the day of terminal screening. At the time of the last screening maximum LAC was noticed on MGG-221 (65.28 %) VGG-7 (53.75 %) Barabanki (52.92 %) and ML-5067 (52.31 %) while SG-1 was found to have the minimum LAC of 14.69 percent.

2. AREA UNDER DISEASE PROGRESS CURVE (AUDPC) VALUES

The area under disease progress curve values were obtained from the disease rating scale namely Leaf Area Covered (LAC).

2.1 Field experiment

Among the 38 genotypes tested under this experiment, highest value was recorded by K-851 which had an AUDPC value of 970.89, followed by LGG-450, MGG-221, GM-84-26, ML-434, ML-459, MUM-3, ML-5067 which had AUDPC values of 956.37, 906.38, 864.54, 861.19, 806.29, 783.73 and 780.91 respectively. Lowest AUDPC value was recorded on UPM-89-9 which was 220.53, followed by GM-85-33, PUSA-105, SG-1 and NDM-53 which showed AUDPC values of 288.74, 361.65, 363.11 and 381.71 respectively. [Table 7].

2.2 Cage house experiment

The severity of powdery mildew was generally low on all the 38 genotypes in this experiment. SMS-1340 recorded the

highest AUDPC value of 515.53. Genotypes PM-89117, RMG-266, K-851, ML-408, Tarm-18, VGG-7 followed with AUDPC values of 395.07, 393.28, 380.79, 311.62, 306.47, 304.61 respectively. The lowest AUDPC values of 53.93 was recorded on UPM-89-9. This was followed by MGG-221, NDM-53 and RKM-9165 with AUDPC values of 110.73, 115.53 and 117.95 respectively. [Table 8].

2.3 Glasshouse experiment

AUDPC values were generated based on LAC for 16 selected genotypes. Disease pressure was high in this experiment. Maximum AUDPC value was recorded on SML-119 (1006.35) which was followed by the genotypes ML-131, MGG-221, PUSA-105 and Barabanki with AUDPC values of 938.22, 905.12, 894.96 and 862.04 respectively. Low AUDPC values of 321.66, 327.61 and 348.18 were recorded on Tarm-18, SG-1 and NDM-53 respectively. [Table 9].

2.4 Cagehouse experiment

AUDPC value was highest on MGG-221 (800.25) and lowest on GM-85-68 (95.08). Genotypes SG-1 and NDM-53 recorded 110.95 and 142.70 respectively. High values of AUDPC were obtained for ML-5067 (577.82), VGG-7 (518.30), ML-5 (507.44), GM-87-28 (503.44) and Barabanki (486.64). [Table 10].

TABLE 8. AREA UNDER DISEASE PROGRESS CURVE VALUES AND APPARENT INFECTION RATES OF SELECTED GENOTYPES SOWN IN GLASSHOUSE ON JULY 17, 1993

SL NO	GENOTYPE	AUDPC	LOGISTIC (r)	APPARENT INFECTION RATES GOMPERTZ (k)
1	Barabanki	862.04 (2.9342)	0.16 (0.3339)	0.065 (0.3148)
2	GM-85-68	440.48 (2.6434)	0.13 (0.3279)	0.043 (0.3102)
3	GM-87-28	555.83 (2.7438)	0.13 (0.3288)	0.047 (0.3112)
4	MGG-221	905.12 (2.9564)	0.20 (0.3419)	0.066 (0.3152)
5	ML-5	701.73 (2.8451)	0.16 (0.3339)	0.071 (0.3162)
6	ML-131	938.22 (2.9701)	0.19 (0.3404)	0.075 (0.3170)
7	ML-267	602.75 (2.7779)	0.14 (0.3294)	0.054 (0.3126)
8	ML-505	618.74 (2.7902)	0.14 (0.3299)	0.052 (0.3122)
9	ML-5067	718.30 (2.8555)	0.18 (0.3379)	0.056 (0.3130)
10	NDM-53	348.18 (2.5392)	0.17 (0.3369)	0.044 (0.3105)
11	PUSA-105	894.96 (2.9470)	0.15 (0.3319)	0.067 (0.3153)
12	SG-1	327.61 (2.5164)	0.16 (0.3339)	0.043 (0.3103)
13	SML-100	479.55 (2.6820)	0.15 (0.3319)	0.048 (0.3113)
14	SML-119	1006.35 (3.0031)	0.22 (0.3457)	0.083 (0.3186)
15	VGG-7	825.58 (2.9145)	0.18 (0.3374)	0.071 (0.3161)
16	TARM-18	321.66 (2.5064)	0.15 (0.3324)	0.045 (0.3107)
	SEM	0.0275	0.0031	0.0008
	CD (5%)	0.0762	0.0086	0.0023

Figures in parenthesis are logarithmic transformed values.

TABLE 10. AREA UNDER DISEASE PROGRESS CURVE (AUDPC) VALUES AND APPARENT INFECTION RATES OF SELECTED GENOTYPES SOWN IN CAGEHOUSE ON SEPTEMBER 7, 1993.

SL NO	GENOTYPE	AUDPC	APPARENT INFECTION RATE LOGISTIC (r)	GOMPERTZ (k)
1	Barabanki	486.64 (2.6858)	0.16 (0.334)	0.076 (0.3172)
2	GM-85-68	95.08 (1.9852)	0.17 (0.3363)	0.063 (0.3144)
3	GM-87-28	503.44 (2.6620)	0.12 (0.3258)	0.060 (0.3138)
4	MGG-221	800.25 (2.8925)	0.11 (0.3248)	0.072 (0.3164)
5	ML-5	507.44 (2.6820)	0.13 (0.3279)	0.066 (0.3151)
6	ML-131	370.00 (2.5630)	0.15 (0.3319)	0.067 (0.3154)
7	ML-267	282.46 (2.4041)	0.13 (0.3289)	0.052 (0.3122)
8	ML-505	352.28 (2.5401)	0.16 (0.3334)	0.066 (0.3151)
9	ML-5067	577.82 (2.7545)	0.12 (0.3258)	0.066 (0.3151)
10	NDM-53	142.70 (2.1596)	0.24 (0.3502)	0.092 (0.3204)
11	FUSA-105	452.51 (2.6553)	0.11 (0.3243)	0.052 (0.3122)
12	SG-1	110.95 (2.0520)	0.19 (0.3399)	0.046 (0.3109)
13	SML-100	305.07 (2.3871)	0.15 (0.3319)	0.065 (0.3149)
14	SML-119	403.99 (2.5742)	0.16 (0.3339)	0.059 (0.3158)
15	VGG-7	518.30 (2.6976)	0.12 (0.3268)	0.070 (0.3160)
16	TARM-18	151.68 (2.1669)	0.14 (0.3299)	0.050 (0.3116)
	SEM	0.0832	0.0031	0.0018
	CD (5%)	0.2307	0.0087	0.005

Figures in parenthesis are logarithmic transformed values

3. RATE OF POWDERY MILDEW PROGRESS

The rate of powdery mildew progress was calculated employing both the Logistic (r) and the Gompertz (k) models.

3.1 Powdery mildew growth rate in the field experiment

The rates of powdery mildew progress on the 38 genotypes calculated on the basis of LAC, employing Logistic (r) and Gompertz (k) models are presented in Table 7. The 'r' value was highest for GM-85-33 (0.51) and lowest for ML-537 (0.17). Significantly high 'r' values were also recorded for the genotypes ML-408, PDM-219, SML-119, SMS-1340, VGG-7 and WGG-35. When the growth rate was calculated by the Gompertz (k) model highest value was obtained for LGG-450 (0.125) while VGG-7 (0.038) and GM-87-28 (0.041) recorded the lowest 'k' values. Barabanki, ML-434 and RMG-266 recorded significantly high 'k' values.

3.2 Growth rate of powdery mildew in the cage house experiment

The value of 'r' was maximum for ML-131 (0.32). The 'r' values for Barabanki, LGG-450, ML-5, ML-337, ML-505, SMS-1340 were significantly high. There was however no significant difference between UPM-89-9 which recorded lowest 'r' value of 0.14 and NDM-53, NGG-335, SML-119, WGG-35 and RKM-9165. The 'k' values was maximum for SMS-1340 and ML-505 (0.111) and minimum for MGG-335 (0.038). The values

were also high for Barabanki, GM-84-26, GM-85-68, K-851, LGG-450 etc. [Table 8].

3.3 Powdery mildew growth rate on selected genotypes

3.3.1 Glasshouse experiment

Higher 'r' value among the 16 genotypes is as follows viz., SML-119 (0.22) followed by MGG-221 (0.20) and ML-131 (0.19) and lowest for GM-85-68 and GM-87-28 (0.13). The 'k' values was highest for the genotype SML-119 (0.083) while significantly high 'k' values were also recorded for ML-131, ML-5, Barabanki, VGG-7, PUSA-105. There were no significant differences between SG-1 which recorded the lowest 'k' value of 0.043 and GM-85-68, NDM-53 and GM-87-28. [Table 9].

3.3.2 Cagehouse experiment

The Logistic infection rate (r) in the cage house was found maximum on the genotype NDM-53 (0.24) and minimum for VGG-7, ML-5067 and GM-87-28 all of which recorded 'r' values of 0.12 while the 'k' values was also highest for the genotypes NDM-53 (0.092) and lowest for SG-1 (0.046). [Table 10].

4. AVERAGE AUDPC VALUES AND INFECTION RATES

The average AUDPC values and infection rates (average of four experiments) have been presented in Table 11. Average AUDPC values was least on SG-1 (238.62) followed by NDM-53 (247.03), and maximum on MGG-221 (680.62) followed by

TABLE 11. AVERAGE AUDPC VALUES AND INFECTION RATES (AVERAGE OF FOUR EXPERIMENTS) OF THE SELECTED GENOTYPES

SL NO	GENOTYPE	AVERAGE AUDPC	AVERAGE 'r'	AVERAGE 'k'
1	Barabanki	581.92	0.23	0.085
2	GM-85-68	315.97	0.21	0.061
3	GM-87-28	431.00	0.19	0.055
4	MGG-221	680.62	0.22	0.073
5	ML-5	478.62	0.20	0.081
6	ML-131	539.10	0.21	0.074
7	ML-267	393.205	0.19	0.064
8	ML-505	441.37	0.22	0.072
9	ML-5067	579.50	0.19	0.069
10	NDM-53	247.03	0.20	0.066
11	PUSA-105	478.15	0.19	0.066
12	SG-1	238.62	0.23	0.055
13	SML-100	369.89	0.21	0.059
14	SML-119	526.02	0.25	0.067
15	VGG-7	572.76	0.22	0.065
16	TARM-18	293.27	0.19	0.062

Barabanki (581.92) and ML-5067 (579.5). The logistic infection rate (r) was found to be maximum on SML-119 (0.25) and the minimum of 0.19 was recorded by GM-87-28, ML-267, ML-5067, Pusa-105 and Tarm-18. The Gompertz infection rate (k) was maximum on Barabanki (0.085) and minimum on SG-1 (0.055).

5. COMPONENTS OF POWDERY MILDEW RESISTANCE

In order to clearly quantify the resistance to powdery mildew, various components of resistance viz., colony size (Sq.mm), conidia per Sq.mm were recorded, in the sixteen selected genotypes.

5.1 Glasshouse experiment

Maximum colony size was recorded in MGG-221 (42.45 Sq.mm) followed by SML-119 and ML-5067 which was 42.14 Sq.mm and 37.04 Sq.mm respectively. Least colony size was recorded in SG-1 (10.04 Sq.mm). The conidia per colony was maximum in SML-119 (11200) followed by Barabanki (10560). The least number of conidia recorded in NDM-53 (2106), ML-267 (2117) and SG-1 (2197). The conidia per Sq.mm was highest in Barabanki (458.53/Sq.mm), followed by SML-119 (265.78/Sq.mm). It was lowest in MGG-221 (63.44/Sq.mm). [Table 12].

5.2 Cagehouse experiment

The result of the study indicated that MGG-221 had the highest colony size of 38.63 Sq.mm followed by ML-267 (37.55

TABLE 12. QUANTIFICATION OF THE COMPONENTS OF PARTIAL RESISTANCE ON 16 GREENGRAM GENOTYPES SOWN IN GLASS HOUSE ON JULY 17, 1993.

SL NO	GENOTYPE	COLONY SIZE IN SQ.MM	CONIDIA PER COLONY	CONIDIA PER SQ.MM
1	Barabanki	23.02 (1.3877)	10560 (4.0207)	458.53 (2.6604)
2	GM-85-68	19.88 (1.3311)	5200 (3.7099)	261.56 (2.4148)
3	GM-87-28	23.45 (1.4019)	4000 (3.5987)	170.57 (2.2335)
4	MGG-221	42.45 (1.6478)	2333 (3.4080)	63.44 (1.7947)
5	ML-5	24.17 (1.3877)	3680 (3.5080)	152.25 (2.1317)
6	ML-131	30.97 (1.5709)	3146 (3.4931)	101.59 (2.0105)
7	ML-267	12.39 (1.1551)	2117 (3.3387)	153.67 (2.3116)
8	ML-505	33.52 (1.5428)	3199 (3.4931)	95.45 (1.9769)
9	ML-5067	37.04 (1.5785)	3413 (3.5283)	92.14 (1.9689)
10	NDM-53	20.69 (1.3463)	2106 (3.3126)	101.80 (2.0053)
11	PUSA-105	20.64 (1.3369)	2304 (3.3408)	111.62 (2.0341)
12	SG-1	10.04 (1.0935)	2197 (3.2786)	204.58 (2.1907)
13	SML-100	32.02 (1.5798)	2900 (3.4412)	90.57 (1.9458)
14	SML-119	42.14 (1.6395)	11200 (4.0338)	265.78 (2.4125)
15	VGG-7	21.94 (1.3691)	3839 (3.5727)	175.01 (2.2364)
16	TARM-18	27.27 (1.4619)	4159 (3.6079)	152.54 (2.1779)
	SEM	0.0354	0.0538	0.0529
	CD (5%)	0.0982	0.1492	0.1467

Figures in parenthesis are logarithmic transformed data

Sq.mm) and Barabanki (34.60 Sq.mm). It was least in SML-119 (10.51 Sq.mm), followed by NDM-53 (13.33 Sq.mm) and SG-1 (15.41 Sq.mm). Barabanki recorded the highest number of conidia per colony (8960), and lowest in SG-1 (2064) and NDM-53 (2133). The conidia per unit area was found to be maximum in SML-119 (398.33/Sq.mm) followed by GM-85-68 (273.88/Sq.mm) and minimum in ML-5067 (120.17/Sq.mm), PUSA-105 (127.24/Sq.mm) and SG-1 (133.93/Sq.mm). [Table 13].

6. EFFECT OF WEATHER FACTORS ON THE DEVELOPMENT OF POWDERY MILDEW

The role of weather factors viz., relative humidity I and II maximum and minimum temperatures and rainfall on the development of powdery mildew was assessed in the field and cage house experiments on the genotypes NDM-53 and Barabanki. The data were analysed by simple correlation analysis and are presented in the Table 14., and the progress of mildew has been compared with the weather parameters. [Figures 2 & 3].

In the field experiment, sown on November 9th 1992, the average relative humidity I and II maximum and minimum temperatures during the disease progress were 83.05 %, 39.02% 26.19 ° C and 12.62 ° C respectively. There was no rain during this cropping period. Under the situation the disease was initiated at the 39th DAS. NDM-53 developed maximum disease severity of 28.03 % (63 DAS) while Barabanki

TABLE 13. QUANTIFICATION OF THE COMPONENTS OF PARTIAL RESISTANCE ON 16 GREENGRAM GENOTYPES SOWN IN CAGEHOUSE ON SEPTEMBER 7, 1993

SL NO	GENOTYPE	COLONY SIZE IN SQ. MM	CONIDIA PER COLONY	CONIDIA PER SQ. MM
1	Barabanki	34.60 (1.5604)	8960 (3.9467)	258.95 (2.4109)
2	GM-85-68	20.68 (1.3538)	5664 (3.7274)	273.88 (2.4152)
3	GM-87-28	19.73 (1.3335)	3573 (3.5477)	181.09 (2.2572)
4	MGG-221	38.63 (1.6058)	5600 (3.7405)	144.96 (2.1596)
5	ML-5	20.82 (1.3550)	4480 (3.6395)	215.17 (2.3251)
6	ML-131	22.82 (1.3905)	3226 (3.5009)	141.37 (2.1468)
7	ML-267	37.55 (1.5881)	5760 (3.7385)	153.38 (2.1699)
8	ML-505	29.75 (1.4974)	6720 (3.8145)	225.87 (2.3449)
9	ML-5067	33.28 (1.5452)	3999 (3.5568)	120.17 (2.0429)
10	NDM-53	13.33 (1.1794)	2133 (3.3081)	160.03 (2.1897)
11	PUSA-105	19.28 (1.3187)	2453 (3.3830)	127.24 (2.1045)
12	SG-1	15.41 (1.2317)	2064 (3.3102)	133.93 (2.1285)
13	SML-100	27.29 (1.4616)	4560 (3.6580)	167.08 (2.2270)
14	SML-118	10.51 (1.0863)	4186 (3.6162)	398.33 (2.5966)
15	VGG-7	16.15 (1.2485)	4159 (3.6079)	257.56 (2.4030)
16	TARM-18	28.10 (1.4673)	4798 (3.6624)	170.80 (2.2191)
	SEM	0.0274	0.0536	0.053
	CD (5%)	0.076	0.1485	0.1469

Figures in parenthesis are logarithmic transformed values

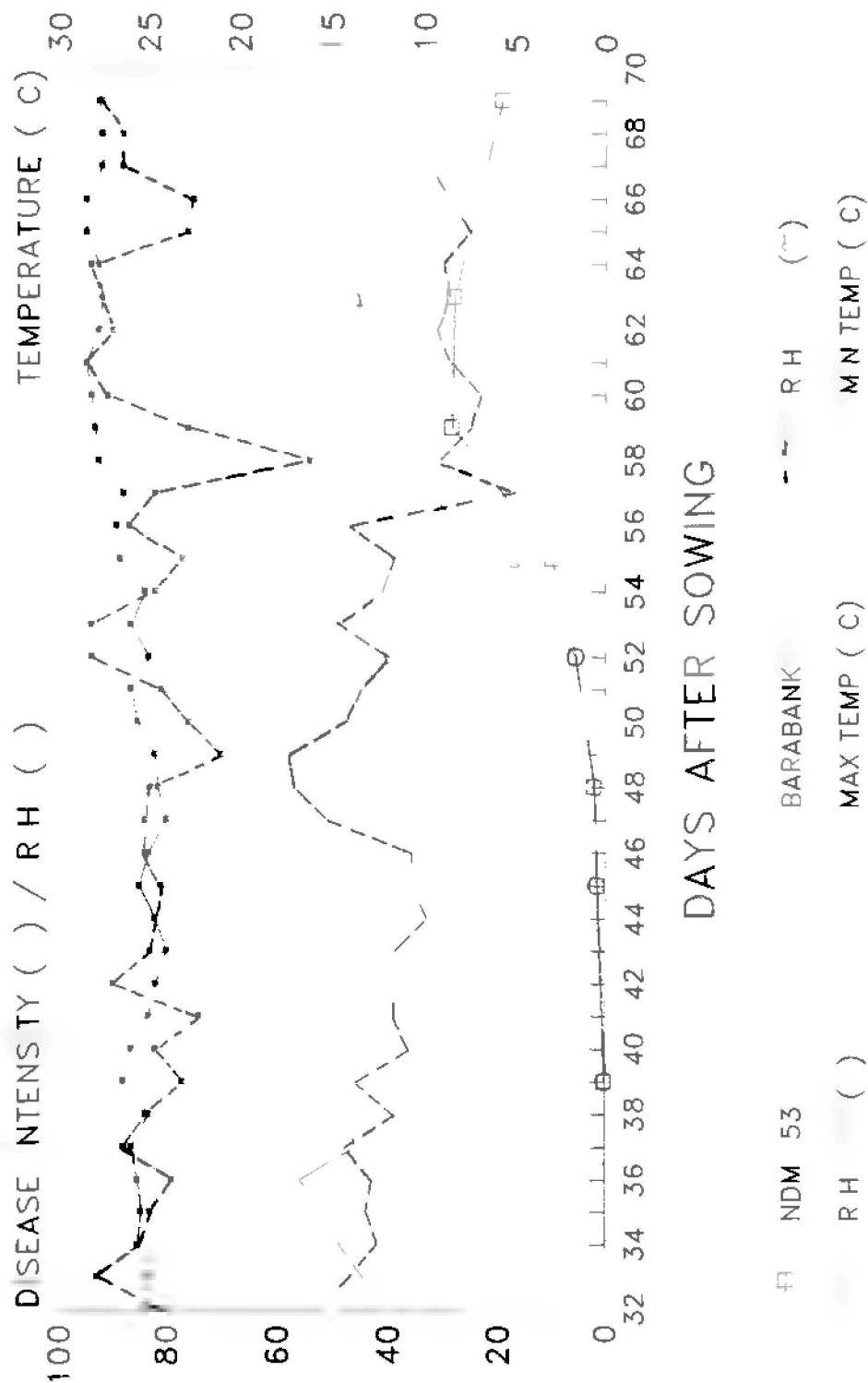


Fig.2 Disease intensity in relation to environmental factors in the field Experiment sown on November 9,1992.

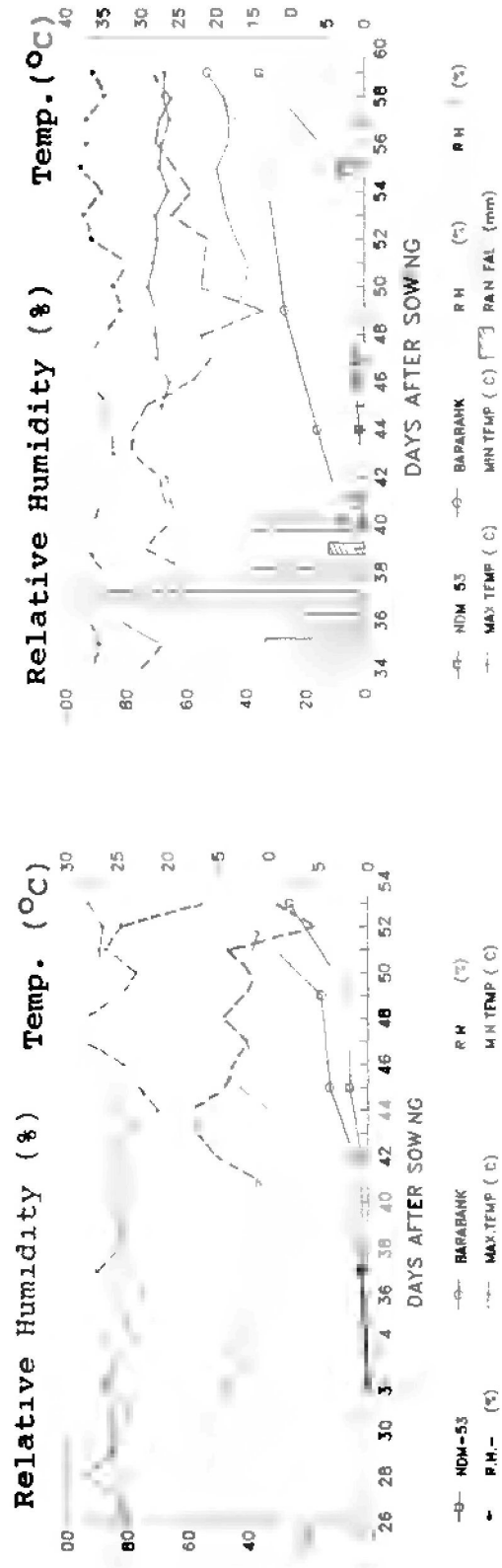


Fig.3. Disease intensity in relation to environmental factors in cagehouse experiments I and II

TABLE 14. CORRELATION VALUES OF POWDERY MILDEW INTENSITY (PERCENT LEAF AREA COVERED) ON NDM-53 AND BARABANKI GENOTYPES OF GREENGRAM WITH THE CLIMATIC FACTORS AT DIFFERENT DATES OF SOWING

DATE OF SOWING	GENOTYPE	RELATIVE HUMIDITY		RELATIVE HUMIDITY		MAXIMUM TEMPERATURE		MINIMUM TEMPERATURE		RAINFALL
		z	r	z	r	Deg.C	r	Deg.C	r	(mm)
09.11.92	NDM-53	-0.0322	NS	-0.7673	*	0.8868	*	-0.2215	NS	---
	BARABANKI	0.0737	NS	-0.7923	*	0.9184	*	-0.0136	NS	---
14.11.92	NDM-53	-0.1851	NS	-0.3824	NS	0.6588	NS	-0.5854	NS	---
	BARABANKI	-0.1284	NS	-0.3394	NS	0.6494	NS	-0.5605	NS	---
07.09.93	NDM-53	0.6415	NS	-0.2626	NS	0.3036	NS	0.1739	NS	-0.4179
	BARABANKI	0.3232	NS	-0.6373	NS	0.6549	NS	-0.1533	NS	-0.7246

Note :- * - Significant at 5 % level

NS - Non-significant at 5 % level

had a maximum disease severity of 77.36 % (69 DAS). [Figure 2]. The study indicated that the correlation (r) values of disease intensity with Relative humidity I and maximum temperature were non-significant in both genotypes. The correlation between disease severity and relative humidity II were significant and negative ($r = -0.7673$ for NDM-53 and $r = -0.7923$ for Barabanki). Significant positive correlation values were found between disease severity and maximum temperature in both the genotypes NDM-53 ($r = 0.8868$) and Barabanki ($r = 0.9184$).

In the cage house experiment sown on November 14, 1992, the average relative humidity I and II were 84.26 % and 42.58 % respectively, while the maximum and minimum temperatures were 24.51°C and 12.11°C respectively. No rainfall was recorded during the cropping period. The disease was initiated at the 32nd day after sowing and NDM-53 and Barabanki developed a maximum disease severity of 26.25% (53 DAS) & 46.58% (53 DAS) respectively. [Figure 3].

In the cage house experiment sown on September 7th, 1993, the average relative humidity I, II, maximum and minimum temperatures during disease progress were 88.96 %, 65.42 %, 26.83°C and 18.44°C respectively. The total rainfall from the date of sowing till disease initiation was 465.3 mm. The disease was initiated at 40 DAS. Further during disease progress the total rainfall recorded was only

25.8 mm. Maximum disease severity recorded on NDM-53 and Barabanki was 35.47 % (59 DAS) and 52.92 % (59 DAS) respectively [Figure 3]. However the correlation values between the disease severity and all the weather parameters tested in both the cage house experiments were non-significant in both the genotypes.

7. EARLY EVENTS OF INFECTION

Studies on early events of infection is an important aspect for identification of resistance or tolerant varieties. Hence the early events of infection process were studied on NDM-53 (slow mildewing genotype) GM-87-28 (moderately susceptible) and Barabanki (highly susceptible). Observations were recorded on percentage conidial germination, appressorium formation, average number of germtubes per conidia and the length of germtubes were recorded at six hour interval. The data has been depicted in the Figure 4 and represented in Table 15.

The result of the study indicated that the percentage of conidial germination at six hours was lowest on NDM-53 (19.35%) and highest in Barabanki (53.90%). GM-87-28 was in between the two with 40.37 percent of conidia germinated. The percentage of conidial germination gradually increased with increase in time and was maximum in Barabanki at 42 hours (88.33%) and in NDM-53 it was 80.15 percent at 48 hours.

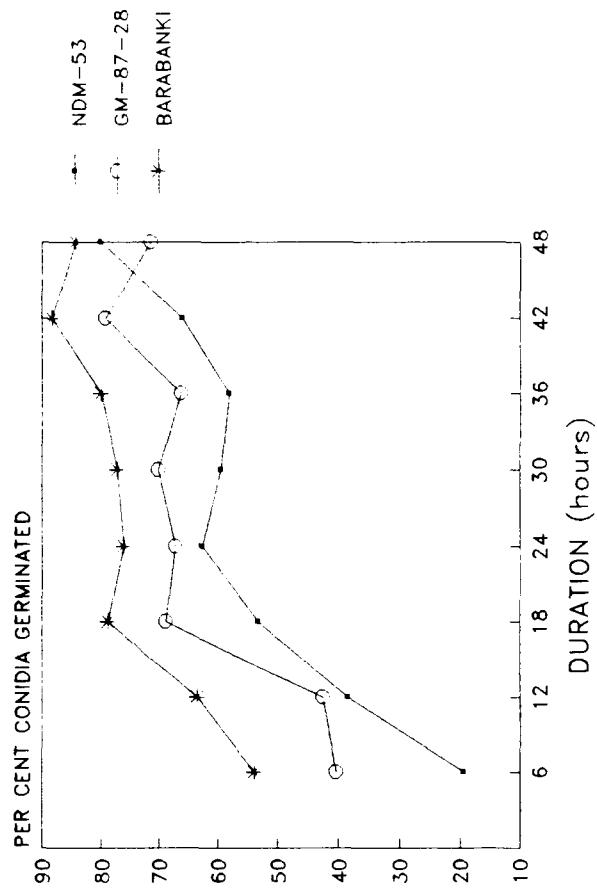
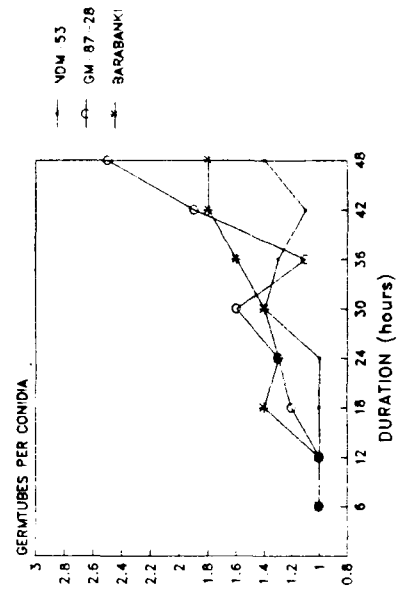
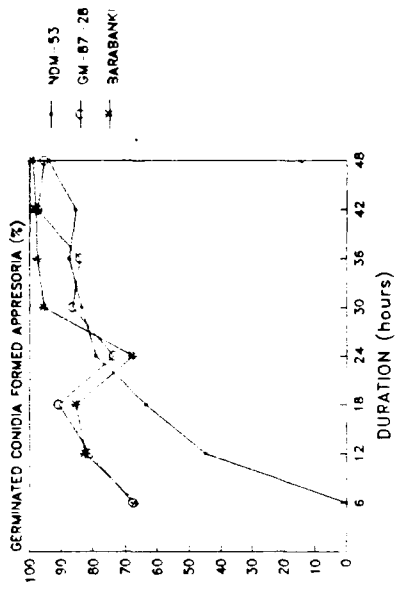


Fig.4. Early events of infection.

TABLE 15. EARLY EVENTS OF INFECTION

DURATION (HOURS)	PERCENTAGE OF CONIDIA GERMINATED	PERCENTAGE OF GERMINATED CONIDIA FORMED APPRESORIA	PERCENTAGE OF GERMINATED CONIDIA FORMED APPRESORIA	AVERAGE NUMBER OF GERMTUBES / CONIDIA	AVERAGE LENGTH OF GERMTUBES (μ)	
	NDM-53	GM-87-28	BARABANKI	NDM-53	GM-87-28	BARABANKI
6	19.35	40.37	53.90	0.00	67.69	66.67
12	38.41	42.59	63.51	44.83	81.16	82.43
18	53.24	68.89	78.89	63.47	90.73	85.36
24	62.66	67.32	76.20	79.18	73.91	67.78
30	59.50	70.10	77.25	83.73	86.59	95.35
36	58.18	66.32	80.00	87.50	84.13	97.50
42	66.00	79.31	88.33	85.45	97.39	98.11
48	80.15	71.43	84.35	94.05	95.30	98.97
54						
60						
66						
72						
78						

The formation of appresoria, expressed as percentage of germinated conidia which formed appresoria was zero in case of NDM-53, 67.69% in GM-87-28 and 66.67 percent in Barabanki at 6 hours. At 48 hours it was 94.05 percent in NDM-53 and 98.97 percent in Barabanki.

The number of germtubes per conidia was maximum in the genotype GM-87-28 (25) followed by Barabanki (1.8) at 48 hours. NDM-53 was found to have only one germtube per conidium upto 24 hours and at 48 hours it had 1.4 germtubes/conidium.

The average length of germtube (μ m) was maximum on Barabanki (340.3 μ m) and minimum in NDM-53 (96.4 μ m) at 72 hours. At the time of first observation i.e, at six hours it was maximum on Barabanki (32.8 μ m) and minimum in NDM-53 (4.1 μ m). The increase in size of the germtubes and development of secondary mycelia have been depicted in the Figure 4 and shown in plates 3 to 6.

8. ESTIMATION OF YIELD LOSS DUE TO POWDERY MILDEW

To work out the loss due to powdery mildew an experiment was laid out during the season and sprayed with effective and recommended fungicide (Carbendizim) with four treatments i.e, no spray one spray two sprays and three sprays on three genotypes namely, NDM-53, PS-16 and Barabanki. The effect of sprays on different genotypes have been shown in plates 8, 9 and 10.



PLATE 1 1 Field view of greengram affected
by powdery mildew



PLATE 2 2 Close-up of healthy and infected
greengram leaflets



PLATE 3 Germination of powdery mildew conidia on Barabanki at 6 hours

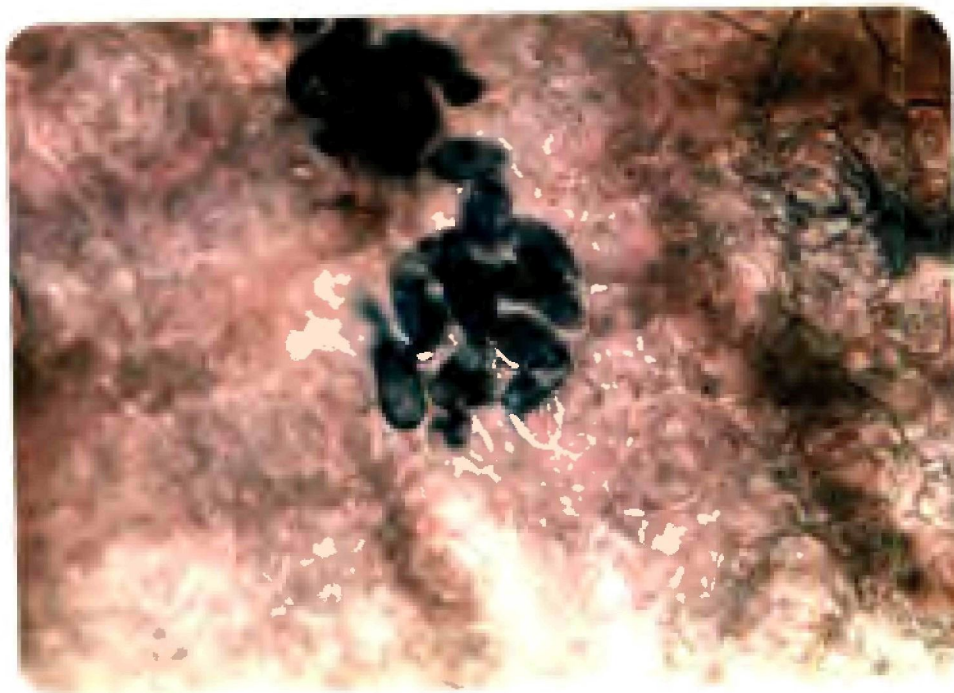


PLATE 4 Germination of powdery mildew conidia on NDM-53 at 6 hours



PLATE 5 5 Development of mycelia on Barabanki at 48 hours

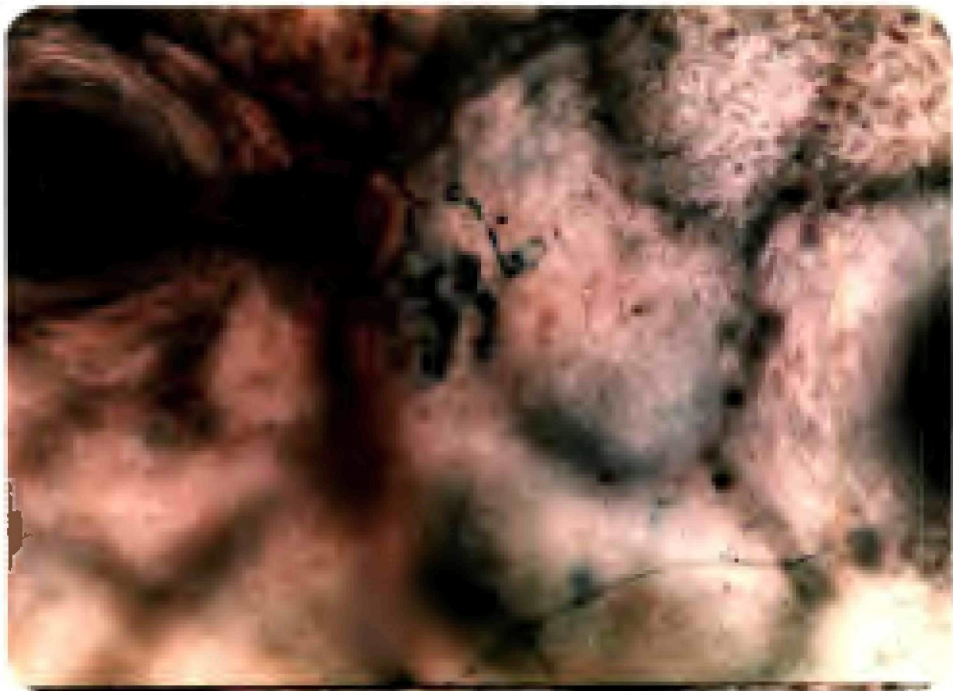


PLATE 6 6 Development of mycelia on NDM-53 at 48 hours

8.1 Disease intensity (%) at 60 DAS

Spraying carbendizim @0.1% controlled the disease significantly (0 to 6.2 %) as compared to control i.e, no spray (20.28 %) [Table 16]. Also spraying carbendizim two and three times controlled the disease to an extent of (0 and 0.02 percent disease severity respectively) as compared to single spray (6.2 %). Among the genotypes NDM-53 recorded lowest disease severity (0.46 %) followed by PS-16 (6.62 %) and Barabanki (12.8 %) which differed significantly from each other.

All genotypes receiving two and three sprays of Carbendizim recorded lower disease severity (0 to 0.07 %). NDM-53 genotype that received no spray of Carbendizim at all recorded a lower disease severity (1.28 %) as compared to Barabanki with one spray (16.03 %). Barabanki recorded higher disease severity (0 to 35.09 %) at all levels of spraying as compared to other two genotypes (0 to 24.46 %).

8.2 Total number of leaves produced

Spraying carbendizim @ 0.1 % had no significant effect on the total number of leaves produced. Among the genotypes Barabanki produced the highest number of leaves (6.94) followed by PS-16 (4.19) and NDM-53 (3.75).

[Table 16].



PLATE 7 Leaflets of different greengram genotypes showing varying degrees of disease severity





PLATE 9 Effect of carbendizim @ 0.1 % on PS-16



PLATE 10 Effect of carbendizim @ 0.1 % on NDM-53

TABLE 16. EFFECT OF CARBENDAZIM @ 0.1 % ON POWDERY MILDEW SEVERITY, CROP GROWTH AND YIELD

TREATMENTS	DISEASE INTENSITY 60 DAS	TOTAL NUMBER OF LEAVES PRODUCED	NUMBER OF LEAVES RETAINED AT HARVEST
	BARABANKI ; PS-16;NDM-53; MEAN ; BARABANKI ; PS-16;NDM-53; MEAN ; BARABANKI ; PS-16;NDM-53; MEAN ;		
NO SPRAY	35.09 ; 24.46 ; 1.28 ; (20.28) ; (5.960) ; (4.92) ; (1.43) ; (4.01) ;	7.00 ; 4.50 ; 3.75 ; 5.08 ;	0.75 ; 1.00 ; 2.50 ; 1.42 ;
ONE SPRAY AT 20 DAS	16.03 ; 2.01 ; 0.57 ; 6.20 ; (4.09) ; (1.55) ; (0.99) ; (2.21) ;	6.25 ; 4.00 ; 3.25 ; 4.50 ;	1.25 ; 2.00 ; 2.25 ; 1.03 ;
TWO SPRAYS AT 20 & 40 DAS	0.07 ; 0.00 ; 0.00 ; 0.02 ; (0.76) ; (0.71) ; (0.71) ; (0.73) ;	7.25 ; 4.00 ; 4.00 ; 5.08 ;	5.25 ; 2.00 ; 2.67 ;
THREE SPRAYS AT 20, 40 & 60 DAS	0.00 ; 0.00 ; 0.00 ; 0.00 ; (0.71) ; (0.71) ; (0.71) ; (0.71) ;	7.25 ; 4.25 ; 4.00 ; 5.17 ;	5.00 ; 3.25 ; 3.5 ; 3.92 ;
MEAN	12.00 ; 6.62 ; 0.46 ; - ; (2.08) ; (1.97) ; (0.89) ;	6.94 ; 4.19 ; 3.75 ; - ;	3.06 ; 1.75 ; 2.56 ; - ;
FOR VARIETIES	F-TEST ; SEM ; CD at 5% ;	F-TEST ; SEM ; CD at 5% ;	F-TEST ; SEM ; CD at 5% ;
	* ; 0.10 ; 0.27 ;	* ; 0.27 ; 0.74 ;	* ; 0.32 ; 0.90 ;
FOR NUMBER OF SPRAYS	* ; 0.11 ; 0.31 ;	N.S. ; 0.31 ; - ;	* ; 0.37 ; 1.04 ;
FOR VARIETIES X NUMBER OF SPRAYS	* ; 0.19 ; 0.53 ;	N.S. ; 0.54 ; - ;	* ; 0.65 ; 1.00 ;

Figures in parenthesis represent angular transformed values.

* ---- Significant at 5 %

8.3 Number of leaves retained at harvest

Significant differences were found in the number of leaves retained at harvest by spraying carbendizim @ 0.1 % [1.83 to 3.92], compared to the control (1.42 leaves). Spraying carbendizim, thrice resulted in more leaves being retained (3.92) compared to the other treatments (1.42 to 2.67). Among the genotypes Barabanki retained the maximum number of leaves at harvest (3.06) followed by NDM-53 (2.56) and PS-16 (1.75).

The genotypes Barabanki retained more number of leaves when given two and three sprays (5 to 5.25 leaves) than when it was given no or only one spray (0.75 to 1.25 leaves). While PS-16 retained significantly more number of leaves at 3 sprays than all other levels. NDM-53 had no significant difference in the number of leaves retained at any level of spray. [Table 16].

8.4 Number of pods per plant

There were no significant differences in the number of pods produced per plant at any level of spray with carbendizim @ 0.1 %. However the genotype Barabanki produced more number of pods per plant (10.15) compared to NDM-53 (8.78) and PS-16 (6.91) and differed significantly from each other. [Table 17].

TABLE 17. EFFECT OF CARBENDAZIM @ 0.1 % ON POWDERY MILDEW SEVERITY, CROP GROWTH AND YIELD

TREATMENTS	NUMBER OF PODS PER PLANT	POD WEIGHT PER PLANT (g)	SEED WEIGHT PER PLANT (g)									
	BARABANKI: PS-16INOM-53: MEAN (BARABANKI: PS-16INOM-53: MEAN (BARABANKI: PS-16INOM-53: MEAN (
NO SPRAY	8.25	5.88	8.50	7.88	4.65	2.38	4.68	3.88	3.20	1.63	2.86	2.56
ONE SPRAY AT 20 DAS	9.17	6.88	9.25	8.10	6.20	3.71	6.01	5.31	2.91	2.66	4.06	3.21
TWO SPRAYS AT 20 & 40 DAS	12.63	6.88	8.13	9.21	9.21	3.33	6.64	6.39	4.61	2.33	4.78	3.90
THREE SPRAYS AT 20, 40 & 60 DAS	10.54	8.00	9.25	9.26	10.59	3.29	8.48	7.45	6.56	2.44	6.64	5.21
MEAN	10.15	6.91	8.78	-	7.66	3.18	6.43	-	4.32	2.26	4.58	-
	F-TEST	SEN	CD at 5%	F-TEST	SEN	CD at 5%	F-TEST	SEN	CD at 5%	F-TEST	SEN	CD at 5%
FOR VARIETIES	*	0.51	1.42	*	0.27	0.75	*	0.19	0.52			
FOR NUMBER OF SPRAYS	N.S.	0.59	-	*	0.31	0.87	*	0.22	0.60			
FOR VARIETIES X NUMBER OF SPRAYS	N.S.	1.03	-	*	0.54	1.51	*	0.37	1.03			

* ---- Significant at 5 %

NS ---- Non-significant

8.5 Pod weight per plant (g)

Significant differences were found in the pod weight per plant by spraying with Carbendizim (5.31 to 7.45 g) as compared to control (3.88 g). Pod weight was maximum when the genotypes were given three sprays (7.45 g) as against two sprays (6.39 g) and one spray (5.31 g) which differed significantly from each other.

All genotypes which received atleast one spray recorded higher pod weight per plant (5.31 to 7.45 g) compared to control i.e, no spray (2.38 to 4.65 g). Pod weight per plant was maximum in Barabanki with three sprays (10.59 g) and minimum in PS-16 (2.38 g) without any spray. [Table 17 and Figure 5].

8.6 Seed weight per plant (g)

Spraying carbendizim @ 0.1 % resulted in significant increase in the seed weight per plant (3.21 to 5.21 g) as against control i.e, no spray (2.56 g). Three sprays resulted in the highest pod yield of 5.21 grams per plant.

Among the genotypes NDM-53 recorded the highest seed weight (4.58 g) followed by Barabanki (4.32 g) which was significantly different from that of PS-16 (2.26 g).

The genotypes Barabanki and NDM-53 recorded higher seed weight per plant at two and three sprays of carbendizim @ 0.1 % (4.61 to 6.64 g). While PS-16 recorded maximum seed

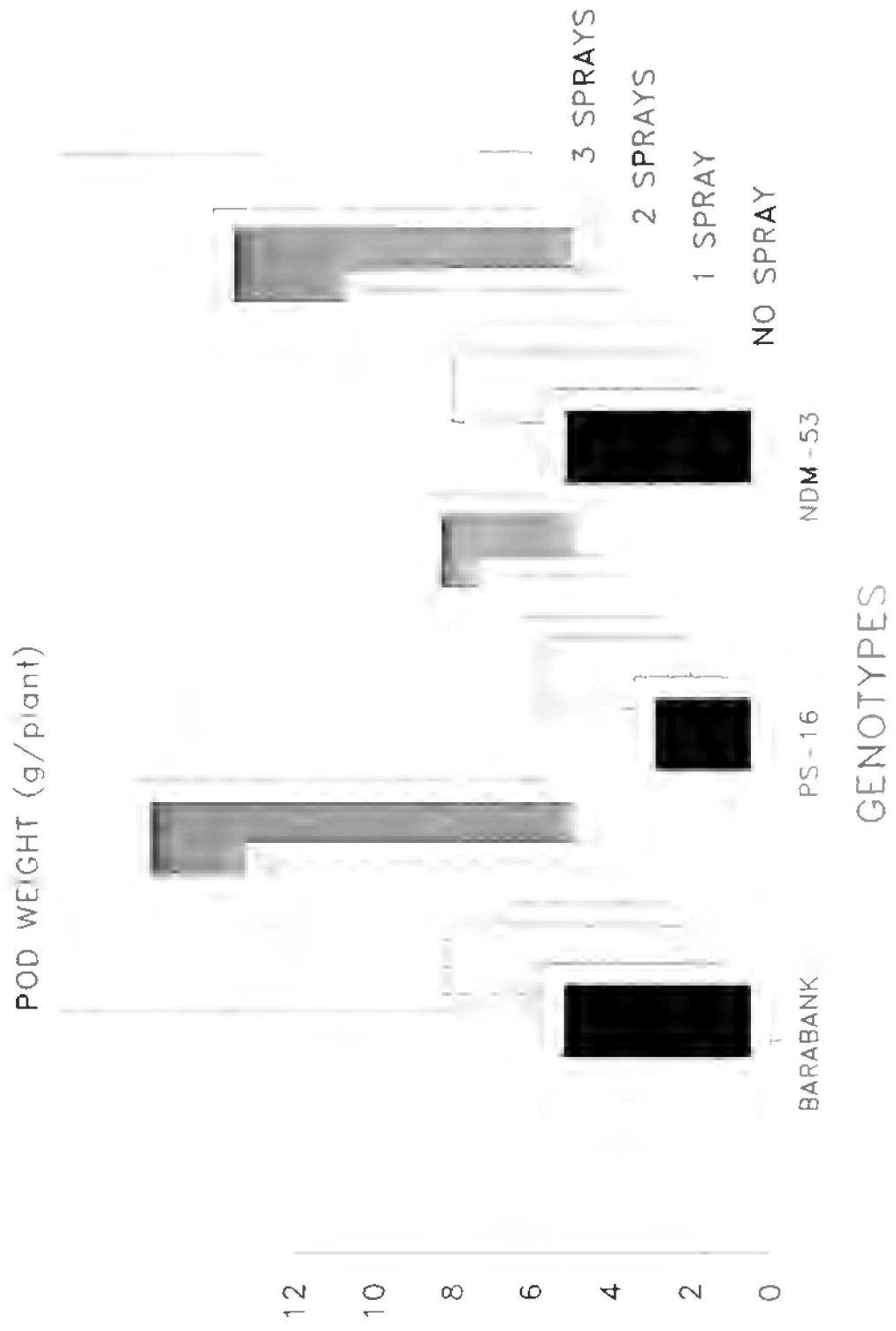


Fig 5. Effect of different number of sprays of 0.1% carbendizim on pod yield of different genotypes.

weight (2.66 g) with one spray. NDM-53 was found to have a seed weight of 4.06 g when given only one spray compared to Barabanki (2.91g) given the same treatment. [Table 17].

8.7 Number of mature seeds per plant

There were significant differences in the number of mature seeds per plant as a result of spraying with carbendizim @ 0.1 % (107.83 to 92.17) as against control (no spray) which recorded 70.92 mature seeds per plant. Among the genotypes, NDM-53 recorded the maximum number of mature seeds per plant (114.81) followed by PS-16 (82.00) and Barabanki (80.63). [Table 18].

8.8 Number of immature seeds per plant

Spraying carbendizim @ 0.1% significantly reduced the number of immature seeds per plant at all spray levels (9.75 to 14.83) compared to the control (no spray) [26.08]. The genotype NDM-53 was found to have the maximum number of immature seeds (23.31) followed by PS-16 (13.56) and Barabanki (9.25). The differences between genotypes at different spraying levels were non-significant. [Table 18].

8.9 Germination percentage

Control of powdery mildew through the spray of carbendizim @ 0.1 % did not have any significant influence on the germination percentage of seeds. However, NDM-53 among the genotypes had a better germination percentage (53.33) followed by Barabanki (50.83) and PS-16 (40.83). [Table 18].

TABLE 18. EFFECT OF CARBENDIZIM @ 0.1 % ON POWDERY MILDEW SEVERITY, CROP GROWTH AND YIELD

TREATMENTS	NUMBER OF MATURE SEEDS PER PLANT	MEAN (BARABANKI PS-16) (MOM-53)	NUMBER OF IMMATURE SEEDS PER PLANT	MEAN (BARABANKI PS-16) (MOM-53)	GERMINATION PERCENTAGE							
NO SPRAY	66.50	157.50	170.92	21.25	120.75	136.25	126.00	60.00	150.00	150.00	153.33	
ONE SPRAY AT 20 DAS	63.75	109.50	123.25	192.17	10.50	111.25	122.75	114.83	50.00	140.00	156.67	140.09
TWO SPRAYS AT 20 & 40 DAS	81.75	191.25	124.00	199.00	2.25	113.50	116.75	110.83	46.67	133.33	150.00	143.33
THREE SPRAYS AT 20, 40 & 60 DAS	110.50	189.75	123.25	107.83	3.00	8.75	117.50	9.75	46.67	140.00	156.67	147.78
MEAN	80.63	182.00	114.81	-	9.25	113.56	123.31	-	50.83	140.83	153.33	-
FOR VARIETIES	F-TEST *	SEM 4.93	CD at 5% 13.66	F-TEST *	SEM 1.47	CD at 5% 4.86	F-TEST *	SEM 3.00	CD at 5% 8.54			
FOR NUMBER OF SPRAYS	F-TEST *	SEM 5.69	CD at 5% 15.77	F-TEST *	SEM 1.69	CD at 5% 4.69	F-TEST N.S.	SEM 3.56	CD at 5% -			
FOR VARIETIES X NUMBER OF SPRAYS	F-TEST N.S.	SEM 9.86	CD at 5% -	F-TEST N.S.	SEM 2.93	CD at 5% -	F-TEST N.S.	SEM 6.16	CD at 5% -			

* ---- Significant at 5 %

NS ---- Non-significant

DISCUSSION

V. DISCUSSION

Greengram is one of the important pulse crops in Karnataka, India. Powdery mildew on greengram is a major threat and causes extensive damage especially under favourable environmental conditions. Control of disease by application of fungicides is not economical and therefore identification of host resistance would be an effective method for reducing loss due to powdery mildew.

Disease resistance is of two types i.e, vertical and horizontal. In vertical resistance, the resistance is controlled by one or few major genes, and is therefore unstable as it can be overcome by the development of new patho types, races of the pathogen. Horizontal resistance on the other hand is controlled by several genes and is generally more stable. This type of resistance has several synonyms like durable resistance, adult plant resistance, partial resistance.

In the present studies 38 genotypes originating from different sources were evaluated for partial resistance to powdery mildew under field, glass house and cage house conditions.

In the present studies a few slow mildewing greengram genotypes were identified by recording the severity of the mildew by repeated screening under varied weather condition

during the disease progress. Out of many cultures screened against the disease the genotypes Barabanki, ML - 5067, VGG-7 and MGG - 221 were highly susceptible while the genotypes NDM - 53, SG - 1, UPM - 89 - 9 were found to possess good level of partial resistance. Several workers have been able to identify slow mildewing or slow rusting genotype in various crops based on the disease progress. Shaner and Finney (1980), identified several slow rusting wheat varieties. Similarly Hartleb et al., (1991) reported barley genotypes that possessed partial resistance to mildew. Luke et al., (1972) employed mildew cover to assess varieties for slow mildewing. Fried et al., (1979) assessed mildew severity on chancellor wheat and four multi lines employing disease progress curves. Raju and Anil Kumar (1990), identified slow mildewing cowpea genotypes on the basis of disease progress.

It is possible to identify partial resistance / slow mildewing genotypes, by means / methods other than disease progress curves. The data collected on several dates during an epiphytotic can be converted into a single statistic which facilitates quantification of the level of resistance and also makes comparisons easier. Vander Plank (1963) suggested the use of apparent infection rate (r) for this purpose. It has been effectively employed by several researchers to recognise partial resistance. [Shaner, 1973

Mackenzie, 1976 Villareal et al., 1980 Kapoor et al. ., 1986].

In the present investigations the rate of disease increase (r) was calculated using LAC. There were variations in the ' r ' values obtained in different experiments. It was however found that high ' r ' values were often associated with higher disease severity and vice-versa. Genotypes SMS - 1340, VGG - 7, Barabanki which were identified to be highly susceptible had higher ' r ' values. While NDM - 53, UPM - 89 - 9, SG - 1, GM - 87 - 28 generally had low ' r ' values.

Berger (1981) highlighted the limitation of apparent infection rate based on Logistic conversion and compared it with Gompertz conversion and concluded that the latter transformation was better.

In the present studies too it was found that the infection rate based on Gompertz conversion was better. For example in the field experiment there was no significant difference in the apparent infection rate based on Logistic conversion between the highly susceptible Barahanki and the partially resistant NDM - 53 genotype but when Gompertz transformation was used the differences were significant. Similar observations were also made in the cage house and glass house experiments.

Several researchers have reported that Gompertz conversion allows a better assessment of the rate of disease development. Chandrashekar et al (1988) studied the rate of rust development in cowpea varieties and found 'k' more useful than 'r'. they found that the Gompertz conversion produced significant differences between genotypes which was not the case when logistic transformation was used. The utility of Gompertz is more evident under low disease pressure where small increases in disease results in great increases in the 'r' compared to 'k'. (Luke and Berger, 1982). Further, in comparative studies of varieties for disease severity, Poyntze and Hyde (1985), found that the Gompertz transformation allowed better comparison than logistic transformation.

The use of infection rate (logistic / Gompertz) as a measure of partial resistance is unsuitable in a crop like greengram, where severe disease levels will result in defoliation. As a result there will be a fall in 'r' and 'k' under such situations. This causes lesser reliability of 'r' and 'k' values.

On the other hand "Area under progress curve" (AUDPC) values which is the summation of values calculated at several intervals during disease progress, is a better epidemiological parameter. Wilcoxson et al (1975), employed

this method to convert rust severity at several intervals into single statistic viz., the AUDPC values.

In the present studies genotypes Barabanki, K - 851, MGG - 221, ML - 5067, VGG - 7, showed higher AUDPC values in all experiments, while the genotype NDM - 53, SG - 1 and UPM - 89 -9 had consistently lower AUDPC values.

Chandrashekar et al., (1989) were able to identify the cowpea varieties subjected to very low rust attack even during rust unfavourable years based on AUDPC values. Steffenson and Webster, (1992) have identified quantitative resistance to Pyrenophora teres in barley on the basis of AUDPC values. AUDPC values have been effectively employed in identifying slow mildewing cowpea genotypes (Raju and Anil kumar, 1990). Similarly slow rusting barley genotypes were identified by Andres and Wilcoxson (1986).

The components of resistance namely colony size, number of conidia per colony, number of conidia per Sq.mm were analysed in the experiments with selected genotypes. The highly susceptible genotypes MGG-221, ML-5067, Barahanki were found to have greater colony size, while the slow mildewing NDM-53 and SG-1 genotypes showed smaller colony sizes. This is in accordance with the work of Arntzen and Parlevliet (1986), Yeh and Bonman (1986) Poyntz and Hyde (1987) and Jacobs and Burlage (1990).

The sporulation capacity expressed as number of conidia per colony or number of conidia per Sq.mm were found to be important components of partial resistance. The susceptible genotypes were found to produce significantly more number of conidia per colony or per Sq.mm than the slow mildewing genotypes. Similar observations were reported by Asher and Thomas (1984) who reported that in case of barley powdery mildew, cumulative total spore production per colony over the 16 day sporulation period differed markedly between the varieties, the most resistant having only one third as many spores as the susceptible control.

Raju and Anil Kumar (1990), also reported that fast mildewing cowpea genotypes produced four times as many spores as compared to partially resistant cultivars against powdery mildew.

The role of weather factors on the development of disease were studied on two genotypes namely NDM-53 and Barabanki. Soria and Quebral, (1973) reported that the incidence of powdery mildew on greengram was highest when the mean temperature and relative humidity were 25.6° C and 85 % respectively.

In the field experiment, sown on November 9th, 1992, the disease was severe on many genotypes. This is probably due to the prevalence of favourable environmental conditions

(Average maximum temperature and Relative humidity of 26.19 Deg.C and 83.05 % respectively). A significant positive correlation was found between disease severity and maximum temperature, while there was a significant negative correlation between relative humidity II and disease severity. In the cage house experiment sown on November 14th, 1992, the disease was initiated earlier than in the first experiment at 32 DAS. This may again be due to favourable environmental factors (Average relative humidity I of 84.86% and the average maximum temperature of 24.51° C. Soria and Quebral, (1973) reported that the incidence of powdery mildew on greengram was highest when the mean temperature and relative humidity were 25.6° C and 85 % respectively. Although correlation values were non-significant, a negative correlation with RH-I and II and minimum temperature and a positive correlation with maximum temperature were found.

However in the cage house experiment sown on September 7th, 1993, the disease appeared relatively late at 40 DAS, inspite of artificial inoculation of 20 day old plants. Also the maximum disease severity was relatively low even though the temperature and RH were favourable for disease development. This is probably due to the high rainfall (465.3mm) from the day of sowing till first appearance of disease, which may have resulted in the poor germination of

conidia in the presence of free moisture, on leaf surface due to continuous rainfall. Similar observations have been made by Lakra, (1990). Heavy rain of long duration interferes with several steps of the infection chain of powdery mildew. First the inoculum in the air is reduced, second the ungerminated conidia on the leaf surface are washed off and finally the conidiophores are destroyed by the impact of big raindrops (Hirata, 1967). There was a negative correlation between disease severity and rainfall in this experiment.

Finally an experiment was carried out to study the early events of infection in the slow mildewing (NDM-53), moderately susceptible (GM-87-28) and highly susceptible (Barabanki) genotypes. The percentage of conidial germination was relatively less on slow mildewing NDM-53 in the initial stages than on the susceptible Barabanki. However with increase in time there was no significant difference the germination percentage of conidia on different genotypes. Similar observations have been made by Carver and Adaigbe (1990).

The percentage of germinated conidia which formed appressoria was maximum on the susceptible cultivars Barabanki and moderately susceptible GM-87-28 at the end of six hours. At the same time none of the germinated conidia had formed appressoria on NDM-53 (slow mildewing genotype).

Appresoria formation was less on NDM-53, upto 12 hours, as compared to the other two genotypes, but subsequently there was no difference between the three genotypes in the percentage of germinated conidia formed appresoria.

Carver and Adaigbe, (1990) found that on adult plant resistant barley cultivars a slightly lower percentage of germlings formed appresoria than on susceptible cultivars. It was found that the number of germtubes / conidia was least in NDM-53 than GM-87-28 or Barahanki even at 48 hours.

The growth of germtubes and secondary mycelia was maximum on the susceptible Barahanki genotype on which the mycelia had grown into an extent of 340.3 um within 72 hours while the mycelial growth on NDM-53 was only to the extent of 96.4 um. Similar observations have been made by (Hite et al, 1977 , Johnson et al, 1979).

Finally an experiment was carried out to determine the yield loss in greengram due to powdery mildew. Powdery mildew was completely controlled by spraying Carbendizim @ 0.1 % two or three times at 20 and 40 DAS or 20, 40 and 60 DAS. However, it was possible to control the disease to the extent of 70 percent with only one spray of Carbendizim @ 0.1 % at 20 DAS. Control of powdery mildew of greengram by spraying Carbendizim @ 0.1 % at different intervals was found to have significant effect in the number of leaves retained at harvest, pod weight per plant, seed weight per plant and the number of mature / immature seeds per plant.

Tiwari and Kotasthane (1986), found that highest yields of mung were obtained by two sprays of Bavistin (carbendizim) @ 0.05 per cent. Kotasthane and Agrawal (1978) found that use of carbendizim to control powdery mildew of greengram significantly improved 100 seed weight.

The pod yield increased by almost 36.8 % with one spray of Carbendizim at 20 DAS. The pod yield increased by 64.6 % and 92 % when the plants were sprayed twice (20, 40 DAS) and three times (20,40 and 60 DAS) respectively with Carbendizim @ 0.1 % at 20 and 40 DAS and 20,40 and 60 DAS. Gupta et al (1975) reported that when greengram powdery mildew was controlled to the extent of 98.5 per cent, yield per hectare was increased to an extent of 27.59 per cent as against 569 kgs/hectare in the control plot. Similar results have been reported by Moghe et al, (1982) Nawaz and Narayanaswamy, (1983).

Griffey et al, (1993), reported the effectiveness of adult plant resistance in reducing grain yield loss due to powdery mildew in winter wheat, and found that grain yields of the slow mildewing Knox 62 genotype without fungicides were equivalent to those obtained with full season control of powdery mildew.

In the present studies it was found that the slow mildewing NDM-53 performed better than the susceptible Barabanki when the disease was not controlled or when only one spray of Carbendizim @ 0.1 % was given at 20 DAS.

SUMMARY

VI. SUMMARY

Thirty eight greengram genotypes originating from different sources were evaluated for partial resistance to powdery mildew, Erysiphe polygoni D.C. These genotypes were tested in field, glass house and cagehouse conditions.

The various parameters employed to assess partial resistance were disease severity (percent leaf area affected) and the epidemiological parameters, infection rate (Logistic and Gompertz transformation) and the area under disease progress curve (AUDPC) values. In addition the components of partial resistance such as number of powdery mildew colonies per leaf, number of conidia per colony, number of conidia per unit area were analysed.

The results of the field, cage house and glass house experiments revealed that the genotypes Barabanki, ML-5067, VGG-7 and MGG-221 were highly susceptible while the genotypes NDM-53, SG-1 and UPM-89-9 were found to possess a good level of partial resistance.

The apparent infection rate values ('r' and 'k') of promising genotypes were often lower than their susceptible counterparts. AUDPC values were found to be a better measure of partial resistance than 'r' and 'k'.

The genotypes behaved similarly with regard to severity, 'r', 'k' and AUDPC values when they were assessed in the cage house / glass house.

The analyses of components of rate reducing resistance indicated that smaller colonies and low sporulation contributed to partial resistance qualities.

In the study of early events of infection it was found that conidial germination was less on slow mildewing genotypes than on susceptible genotypes, in the initial stages only. Low appresorial formation and retarded mycelial growth were found to be associated with slow mildewing genotypes.

Control of powdery mildew by spraying carbendizim @0.1% at different intervals was found to have a significant effect on the growth and yield of greengram.

These studies revealed that a few genotypes NDM-53, SG-1 and UPM-89-9 possess a good level of partial resistance and may be released as cultivars if agronomically feasible or they may be incorporated in breeding programmes for developing slow mildewing varieties.

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