GENETICS OF RESISTANCE TO ALTERNARIA LEAF BLIGHT, DOWNY MILDEW AND POWDERY MILDEW IN MUSKMELON (*Cucumis melo* L.)

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C E R T I F I C A T E

This is to certify that the thesis entitled "**GENETICS OF RESISTANCE TO ALTERNARIA LEAF BLIGHT, DOWNY MILDEW AND POWDERY MILDEW IN MUSKMELON (*Cucumis melo. L*)**" submitted by **Mr. SATHEESHA B. P.** for award of the degree of **DOCTOR OF PHILOSOPHY** in **HORTICULTURE** to the University of Agricultural Sciences, Bangalore is a record of *bonafide* research work carried out by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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CONTENTS

LIST OF TABLES

(Cont....)

LIST OF TABLES

(Cont....)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

Muskmelon (*Cucumis melo*. L) is a popular delicacy and an important vegetable crop. In India this crop is popular in North-India especially in Utter Pradesh and Punjab and is grown in almost every place in the plains. Muskmelon has many vernacular names such as Kharbooza (Hindi), Kharbuz (Punjabi), Sakkartoti (Gujarati), Kalinga (Sanskrit), and Velapalam (Tamil). The species *Cucumis melo* is a large polymorphic taxon encompassing large number of botanical and horticultural varieties or groups. Muskmelon is said to be the native of tropical Africa with Central Asia comprising some parts of Southern Russia, Iran, Afghanistan and North-West India as secondary centers of origin. (Whitakar and Davis, 1962).

Muskmelon (2n=24) belongs to the family Cucurbitaceae. Edible melon belongs to either *Cucumis melo* var *reticulatus* or *C. melo* var *cantaloupensis.*

Plants are either monoecious or andromonoecious annuals with long trailing vines with shallow lobed round leaves. There is a considerable variation in fruit size and shape. External appearance may be smooth with vein tract or netted, the skin colour may be white, green, yellow, yellowish brown or speckles yellow or orange with green or yellow back ground. Fruits of some cultivars abscise when ripe. Upon ripening the fruits soften and fruity aromatic essences are formed in the fruit.

This fruit is highly relished by both rich and poor, young and old. Muskmelon is used as dessert fruit. It has a cooling effect. In its green stage, it is sometimes used as a cooked vegetable in rural areas. The fruit juice is nutritive, demulcent and diuretic drink. The seeds are edible and its kernel is rich in oil (40-44%). Apart from the common usages, muskmelon has got some medicinal value. The fruit juice is beneficial as a lotion in chronic and acute eczema as well as tan freckles, and internally in case of dyspepsia. The pulp mixed with cumin sugar candy is a cooling diet in hot season. The seed oil is useful in painful discharge and suppression of urine. The root of melon in emetic and purgative in action (Nadkarni, 1929).

Muskmelon is a good source of vitamins and minerals. Fruits are relatively low in food value especially protein. The yellow and orange fleshed melons contain β-carotene, provitamin A. Cantaloupe is particularly high in this pigment (4200 I.U/100g). Melons are also high in vitamin C (45mg / 100g edible portion). Apart from this for every 100 gram edible portion, melon provides 26-41 calories energy, 0.6-1.0g protein, 5-10 mg calcium, 0.2-0.4 mg iron, 8-17 mg magnesium and 7-39 mg phosphorus. (Howard *et al.* 1962).

Total area under muskmelon cultivation in the world is estimated to 803,000 ha. with an annual production of 1,38,94,000 metric tones. However data on area under cultivation in India is lacking. The Indian production of muskmelon is estimated to 17,000 metric tones (Annon, 1994).

The vulnerability of this crop to several biotic and abiotic stresses accounts for its low yield potential and in turn the high cost of production. Alternaria leaf blight, downy mildew and powdery mildew are the three major foliar diseases which are responsible for heavy loss in total yield and quality of fruits in cucurbits in general and muskmelon in particular.

There are two distinct Alternaria diseases of cucurbits. One of these is the foliage blight and the other is a fruit rot. On muskmelon, the leaf blight begins as small tan spots which enlarges roughly circular areas, often coalescing to involve most of the leaves. The spots become dark coloured with age often show concentric ridges which give a target board appearance. Complete defoliation may occur, and even partial defoliation expose the fruit to sunscald injury. The leaf blight fungus cause decay of melons in storage.

The causal organism *Alternaria Cucumerina* (Ell and Ev) Ellot belongs to the class Deuteromyceties order Moniliaceae and family Dematiaceae Conidia are obclavate, muriform, dark, measuring 15-25 X 30-75μ.

The very first symptom of downy mildew on muskmelon is the appearance of small, water-soaked lesions on the underside of the leaf. This lesion when viewed from the upper side of the leaf, rapidly assumes various shades of yellow and is covered on the underside by a gray to blackish downy growth. The lesion subsequently becomes necrotic, beginning at the center, while its periphery is still yellowish green. The downy growth is absent from the necrotic tissue on the underside of the leaf except on veins running through the lesion. The discrete lesions measure 6-15mm in diameter. At a later stage the lesions may coalesce giving the leaf a checkered appearance with at first yellow, then brown spots predominating. Eventually the leaf blades become dry and curl upward while the petioles remaining green, but ultimately the petioles also become dry, although the leaf is not shed. (Palti and Cohen, 1980).

Downy mildew is capable of completely destroying crops of muskmelon. However, as with many other diseases, the extent of losses caused depends on the stage of growth at which the crop is attacked. When the first true leaves are attacked, there may be total loss of the crop, but attacks at so early a stage are also infrequent. Attacks at the fruiting stage are destructive everywhere, but attacks beginning later cause only limited damage. (Van Haltern, 1933).

Pseudoperanospora cubensis (Berk and Curt) Rostow belongs to the class Oomyceteis, oder peranosporales and family peranosporaceae. The mycelium is coenocytic and intercellular and gives rise to small, ovate intracellular haustoria, which sometimes develop finger like branches. Sporangiophores arise in groups of one to five through the stomata. The upper third of sporangiophore is branched, either dichomously or intermediately between the dichotomus and monopodial branching habits.,

The sporiferous tips on which the sporangia are born are subacute. The later are greyish to olivacious purple, ovoidal to ellipsoidal, thin walled and with a papilla at the distill end. They measure 12-13 X 21-39μ. The sporangia germinate by the production of biciliated zoospores, which are 10 to 13μ in diameter after encystment.

While muskmelon downy-mildew may appear to be favoured by moist and cool environment, it is evident that moisture is the most important factor. This fungus thrives in warm as well as cool temperatures provided fogs or dews are frequent and persistent. Sporangia germinate from about 8-30° C, with optimum reported from 15-22° C (Walker, 1952). About 18° C and 100% RH for 5 hours are required for infection. Rain is not essential if heavy dew prevails. Infection occurs from about 10-28° C with the optimum being 16-28° C. Sporangia are formed from about 10-27° C with an optimum at about 15-19°C. Sporangia are chiefly airborne.

Powdery mildew is another serious disease of muskmelon. Symptoms first appear as white or fluffy, somewhat circular patches or spots which appear on the under surface of the leaves and spread also to the petiole, stem and fruit. Severely attacked leaves become brown and shrivelled and defoliation may occur. Fruits of the affected plants do not develop fully and remain small.

Causal organism of powdery mildew of muskmelon is identified as *Sphaerotheca fuliginea* (Schlecht Fr) Poll. The perfect stage of the fungus has been identified as *Erysiphae cichoracearum* D.C.

The *Sphaerotheca fuliginea* causes a somewhat brownish fruiting body on the foliage while that of the *Erysiphae cichoracearum* is flour-white. The Sphaerotheca has branched appendages on its dark globular fruiting bodies, which usually contain only one ascus. The Erysiphae has mostly unbranched appendages and more than one ascus in each perithecium.

Erysiphae cichoracearum belongs to class Ascomycotina, order Erysiphales and family Erysiphae. The fungus is known to produce the oideal or conidial stage as well as the perfect stage. The mycelium is superficial and spreading on the leaf surface, and the hyphae draw the nutrients by sending haustoria into the epidermal cells of the host plant. They produce conidiophores almost at right angles to the host surface. The conidiophores are hyaline, thin walled and bear chains of conidia which are also hyaline and thin walled and are oblong, measuring 20-30 x 15-20µ. The

clestothecial stage is formed later on as the disease advances. The clestothesia which are scattered over the affected plant parts, are dark coloured, spherical with thick walled appendages and measures 80-140μ in diameter. They contain numerous asci which are subcylendrical measuring 60-90 X 30-35μ. Each ascus contain two or three ascospores which are hyaline, elliptic and thin walled measuring 20-28 X 12-20μ.

The mycelium of *Sphaerotheca fuliginea* is hyaline, occasionally brown when old, usually evanescent but sometime persistent. Conidia are formed in long chains. They often show fibrosin bodies and are ellipsoidal to barrel shaped, 25-37 X 14-25μ in size. Clistothecia are scattered to densely gregarious 66-98μ in diameter, usually under 85μ. The wall cells are usually 25μ wide. Appendages are variable in number, myceloid, brown and as long as ascocarp. Asci are broadly elliptic to subglobose and measures 50-58 X 27-60μ. Each ascocarp contain a single ascus. There are eight ascospores in the ascus. They are elipsoidal to nearly spherical and measures 17-22 X 12-20μ.

Infection by powdery mildew fungi is greatly influenced by the stage of the plant, air humidity and temperature. 16-23 days old leaves are highly susceptible while very young leaves are almost immune. The fungi can sporulate and cause infection in very dry as well as wet atmosphere. The minimum and maximum temperature for conidial formation and host penetration are 10^0 C and 32^0 C optimum being about $26\text{-}28^0$ C (Singh, 1987).

The losses caused by these foliar diseases to yield and quality of muskmelon could be prevented either through protective fungicidal spray or deploying disease resistant cultivars. The ecological amplitude of these pathogens in infecting its principal hosts, and the comparatively marked ability of their spores to survive somewhat uncongenial conditions, coupled with the fast growth of muskmelon under good conditions along with the difficulty of covering the underside of foliage close to the ground with fungicide - all these factors restrict the efficacy of fungicidal control of these foliar diseases and point to breeding for resistance as the most promising control measure.

In India, at present, there are no muskmelon varieties bred for resistance to all the three diseases. During the past years several sources of resistance in melon for downy mildew, powdery mildew and Alternaria leaf blight have been identified by different workers; however, the genetics of resistance to these diseases, which is a prerequisite for effective planning and executing a breeding program is lacking in muskmelon from India. Apart from this, the biochemical aspects such as leaf composition of sugars, starch, and phenols will help in the better understanding of mechanism of resistance to these diseases in resistant sources.

The present study was under taken at the Division of Vegetable Crops, Indian Institute of Horticultural Research (IIHR), Hesaraghatta, Bangalore with the following objectives,

1) To study the genetics of resistance to Alternaria leaf-blight, downy mildew and powdery mildew in muskmelon

2) To study the development of disease at various stages of crop growth in susceptible variety Arka Jeet and the correlation between weather factors and disease development

3) To study the correlation between reducing sugar, non-reducing sugars, total sugar and total phenol and disease resistance in muskmelon.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Alternaria leaf blight [*Alternaria cucumerina* (Ell and Ev) Ellot], downy mildew (*Pseudoperanospora cubensis* (berk and curt) Rostow] and powdery mildew [*Sphaerotheca fuliginea* (Schlecht. Fr) Poll, and Erysiphe cichoracearum D.C] are the three major foliar diseases of muskmelon responsible for large reduction in yield and quality of the fruits. Information on genetics of these diseases would be most useful in planning and execution of breeding programs to evolve a new variety or hybrid which is resistant to these diseases. Several studies have been reported on Alternaria leaf blight, downy mildew and powdery mildew of muskmelon. Since the causal organisms and symptoms are almost similar, a review of literatures related to the present study from other members of the family Cucurbitaceae and other vegetables is also summarised along with *Cucumis melo* L. under the following headings

2.1 Causal organism/races

2.2 Environmental factors of disease development

2.3 Sources of resistance

2.4 Genetics of resistance

2.5 Mechanism of resistance

2.1 CAUSAL ORGANISM / RACES.

2.1.1 Alternaria leaf blight

Galliotti (1988) identified the isolated fungus from muskmelon leaf as *Alternaria cucumerina* based on its cultural and morphological characters. It was the first report of this fungus on muskmelon in the province of Mendoza.

Vakalounakis (1990) recorded the symptom of a leaf spot disease as necrotic flex surrounded by chlorotic halos developed on the cotyledons and the leaves of the middle and upper parts of the plants; the flex expanded and coalesced to form lesions of 2 cm or more in diameter with brown fruitification of the pathogen on their surface. He identified the fungus as *Alternaria alternata* f.sp. cucurbitae. of different isolates, only the cucumber isolate was pathogenic to melon foliage.

Vakalounakis (1989) noticed an infectious leaf spot disease in green house crops of cucumber which has caused severe losses. Spore dimensions from *in vitro* and *in vivo* cultures of the pathogen agreed with published descriptions of *Alternaria alternata*

Alternaria cucumerina was isolated for the first time in Egypt from lesions of young watermelon leaves. The isolates were pathogenic to both cotyledons and true leaves of watermelon but varied in virulence. The minimum period of exposure to high relative humidity necessary to induce infection on incubated leaves was 18 hours. (Ibrahim *et al.*, 1975).

2.1.2 Downy mildew

Downy mildew of cucurbits first recorded from Cuba in 1868 (Berkely and Curtis, 1868) the principal feature dividing Pseudoperanospora from Peranospora is that the spore wall in the latter is non-poroid, uniformly thick and germination can only be by germ tube, where as the spores of Pseudoperanospora are true sporangia with a poroid apex and germinate by zoospores. (Barnes and Epps, 1954).

Bains and Jhooty (1976a), in India (Punjab) searched for but failed to detect oospores on diseased leaves of *Cucumis melo*, *C. callosus*, *Luffa acutangula* and *Lagenaria siceraria.*

Downy mildew symptoms on *Luffa acutangula* and *Lagenaria siceraria* are similar to those on melon, while on *Luffa aegyptiaca* and *Benincasa hispida* lesions coalesced more slowly and were invariably purplish in colour. (Bains and Jhooty 1976b).

Vardy and Ducrot (1985) observed a heavy loss due to downy mildew in glass house grown cucumbers in North East Switzerland. They found that the disease generally spreads by wind borne spores, which germinate in the presence of water on mature leaves. They advised to avoid wetting of leaves in glass house and good ventilation to control downy mildew in glass houses.

Bains and Sharma (1986) identified two new races of *Pseudoperanospora cubensis* on muskmelon from Punjab. The new races differed in host range from others. Race M1 being pathogenic to 4 of 9 cucurbitaceous crops tested and M2 to 7.

Inaba *et al.* (1986) found no significant differences in the morphology of conidia and conidiophores among the two cucumber (c1 and c2) and two muskmelon (M1 and M2) isolates of downy mildew. The existence of 3 races (cucumber race 1, Cucumber race 2 and muskmelon race 1) was demonstrated. Two out off 6 cucumber, all of 6 *Cucumis melo* Var. acidilus, all of 5 c melo var conmon, all of 4 *Cucumis melo* var *reticulatus* and F_1 hybrid (*C. melo* var. *acidilus* X *C. melo* var *cantaloupensis*) were highly susceptible to the muskmelon race 1.

Brunelli and Davi (1987) reported that attacks of *Pseudoperanospora cubensis* especially on cucumber and melons have increased in the field and in the glass houses in Italy. Symptoms and damage, biological characters of the pathogen, epidemiology and control were discussed.

2.1.3 Powdery mildew

Rudenko and Golub (1973) found that almost all the 200 cucumber varieties studied were severely affected at the cotyledon phase regardless of their resistance as adult plant. *Erysiphae cichoraciarum* was a more virulent pathogen than Sphaerotheca fuliginea. However Gruger (1977) observed that *Sphaerotheca fuliginea* affects plants in the green house and *Erysiphae cichoracearum* those in the field.

Thomas (1978) reported a new biological race of *Sphaerotheca fuliginea* as race 3 on muskmelon. This race is more aggressive than the earlier reported ones.

Ullas et.al. (1979) studied the occurrence of perithecial stage of *Sphaerotheca fuliginea* on muskmelon from Bangalore and found that perithecia developed on old heavily infected leaves where maximum and minimum temperatures were 27^0 C and 12.7^0 C and R.H 22-51%

Sowell (1982) observed a population shift of Sphaerotheca fuliginea on muskmelon from race 2 which was predominant in 1969 to race 1 which was apparently predominated in USA during 1974.

Kour and Jhooty (1987) confirmed the presence of race 3 of *Sphaerotheca fuliginea* on muskmelon in Punjab by the reactions of 4 differential cultivars.

Branjanti and Brunelli (1992) stated that *Erysiphae cichoracearum* attacks marrow and cucumber in April to June and *Sphaerotheca fuliginea* in the summer and autumn. On melon the disease is mainly caused by *Sphaerotheca fuliginea.*

2.2 ENVIRONMENTAL FACTORS

For any disease to cause economic damage to the host crop, favourable environmental conditions such as temperature, relative humidity and light intensity are

very important. Alternaria leaf blight and downy mildew of muskmelon are the two diseases which require high humidity, moderate temperature and intermittent rainfall. A thin film of water on leaf surface will greatly enhances the spore germination and penetration in to leaf tissue. On the other hand, powdery mildew of muskmelon requires a relatively cool temperature and dry weather to cause economic damage. By mere adjusting cropping season, one can avoid a particular disease. Some of the reviews on environmental factors which influence the development of Alternaria leaf blight, downy mildew and powdery mildew are presented in this section.

2.2.1 Alternaria leaf blight.

Jackson (1959) reported that germ tube development, intracellular growth of hyphae and serious out break of alternaria leaf blight occurred on muskmelon when temperature ranged from 20-32° C. They also noticed that free moisture on leaf apparently was not critical.

Khandelwal and Prasad (1970) studied the growth requirement of *Alternaria cucumerina* and reported that fungus required 25-30° C and 92-100% relative humidity for maximum growth and sporulation. However, typical symptoms on muskmelon were produced with in 5 days after inoculation at a temperature of 25-27° C (Chahal *et al.* 1970).

Singh (1980) found that a temperature of 22° C and pH of 5.5 were optimum for the sporulation of *Alternaria brassicae* which causes blight in cabbage.

In another study Degenhardt *et al* (1982) observed that *Alternaria brassicicola* had a higher temperature requirement than *Alternaria brassicae* and *Alternaria raphani.* A relative humidity >95% was required by *Alternaria* sp for conidial germination. With dew periods of 6-8 hours, at <15° C, the germination of *Alternaria* sp was very low.

Humperson-Jones *et al.* (1983) stated that *Alternaria bassicae* and *Alternaria brasicicola* both required free water with optimum temperatures of 15 and 25° C respectively for infection of cabbage plants.

Norton and Boyhan (1983) studied the resistance to *Alternaria cucumerina* in muskmelon. They found that a temperature of 25° C and relative humidity to near saturation (100%) for 48 hours enhanced the development of disease.

Boyhan and Norton (1984) reported that Alternaria leaf blight appeared to be more severe during the periods of high rainfall and high humidity often associated with summer rain.

2.2.2 Downy mildew

Onset of an epiphytotic of the disease depends on the overall effects of weather on the seasonal development of the pathogen. The limiting point in every epidemiological considerations of *Pseudoperanospora cubensis*, as with other downy mildews, is leaf wetness. Unless free moisture is available on the leaf surface for germination of sporangia and for penetration of germ tubes in to the host, all other factors become irrelevant.

Duvdevani *et al.* (1946) reported that in the absence of rain, prevention of dew largely precludes the development of disease on cucumber in Israel under conditions in which exposure to dew leads to severe incidence of disease. Small amount of downy mildew that developed on plant protected from dew fall may have been due to the presence of guttation moisture. They also found that irrigation by sprinkling increased the rate of guttation under condition of little or no dew and changes the conditions in favour of disease.

Thomas (1977) observed that dew periods were to be the determining factors for the onset of downy mildew on cantaloupes in Southern Texas. Epiphytotic did

not occur until dew periods were of atleast 5-6 hours duration although inoculum was present and temperatures were favourable.

Cohen (1977) studied the infection of susceptible leaves of cucumber under controlled conditions in a factorial experiments with 72 combinations of temperature, inoculum concentrations and leaf wet durations. He found that the maximum, minimum and optimum levels of each factor for symptom formation depended on one or both of the other factors. Minimum temperature for infection was 20° C with 2 hours of wetness, decreasing to 10-15° C and 5-10° C with 6 and 12 hours of wetness, respectively. An inoculum of 10 sporangia/cm^2 was minimum for infection under favourable temperature and wetness of leaf. Optimum inoculation concentration was 1000 sporangia/cm^2 under most conditions.

Bains and Jhooty (1979) reported the development of *Pseudoperanospora cubensis* on muskmelon in Punjab in the months with mean temperature of 29-30° C, 30-32° C and 28-30° C with maximum reaching 44° C even 48° C. The disease in the field continued to develop in these months, although established infections in the laboratory studies were eliminated in plants exposed for six hours to 40-45° C. The temporary reduction in the temperature effected by occasional rainfall and long wet periods, were considered to maintain the disease even under these extreme conditions.

Palti and Cohen (1980) reported that rain played an important role in mildew development. Rainfall during day time extend wetness period beyond those provided by dew at night. Rain penetrates to most of the lower leaves and may also splash inoculum when conditions for infection are favourable.

Pseudoperanospora cubensis infected cucumber in dark or light. Infection at 20° C was markedly enhanced when a short wet period was associated with illumination of relatively low photon flux density. When wetness was applied for 2.5 hours, plants exhibited some diurnal periodicity in proness to infection which was

highest at mid day. The results explained the high incidence of downy mildew in dry seasons in semiarid areas where dew is the major source of free leaf moisture (Cohen and Eyal, 1980).

In a lab study Kuznctsov (1980) found that optimum temperature for sporangial germination of *Pseudoperanospora cubensis* was 14-18^0 C. In water drops at -10 to -1^0 C sporangia maintained their viability up to 15 days and only one day at 30-32^0 C.

Maharishi and Sridharan (1988) observed the arrest of infection and sporulation of *Pseudoperanospora cubensis* on muskmelon at temperature more than 35^0 C. A relative humidity of more than 75% was conducive for disease development. Under field conditions, initiation and further progress of the disease tended to depend mainly on moisture, temperature having a secondary, negative effect on infectivity of air borne sporangia.

2.2.3 Powdery mildew

Abilko and Kishi (1979) reported that high humidity was most conducive to conidial germination of *Sphaerotheca fuliginea*. At later stages of infection low humidity was more favourable.

The development of *Sphaerotheca fuliginea* on cucumber lines appeared to be favoured by a night/day temperature regime of 15/21^0 C rather than one of 21/27^0 C (Munger, 1979).

In garden peas incidence of *Erysiphe polygoni* was high and losses were heavy when temperature was 20-26^0 C with dry weather (Ploper, 1981).

Singh (1987) stated that *Erysiphe cichoracearum* and *Sphaerotheca fuliginea* can sporulate and cause infection in very dry as well as wet atmosphere, but infec-

tion increased as the atmospheric humidity increased. Heavy dew deposition favoured the penetration by the germ tube. The maximum and minimum temperatures for conidial formation and host penetration were 10^0 C and 32^0 C with optimum was about 26-28^0 C.

Lakra (1990) found that conidia of *Erysiphae polygoni* were unable to survive being submerged continuously for 5 hours or more at 21 ± 1^0 C and germination was presented by submergence for 2 hours.

2.3 Sources of resistance

A plant is considered resistant if the disease does not develop in presence of a pathogen under favourable conditions. Resistance according to the plant breeder is the ability of a plant genotype to avoid loss in terms of quality and quantity of plant products due to disease (Sidhu, 1987)

If a new disease resistant cultivar is to be successful, it must be fully as good as the old susceptible cultivar in all features that influences the net value of the crop even when disease is abundant (Andrus, 1953).

Identification of sources of resistance is the first step in breeding for resistance. During the past years, several sources of resistance in musk melon for Alternaria leaf blight, downy mildew and powdery mildew have been identified by different workers in India and elsewhere. Some of the sources of resistance are presented in this part.

2.3.1 Alternaria leaf blight

Hartman and Gay Lard (1944) reported that "Prude 44 cantaloupe" was resistant to Alternaria leaf blight.

Sitterly (1972) found that PI 140471, 145194, 164551, 124109 and 116915 were most resistant to *Alternaria cucumerina*. Edisto and Edisto 47 were moderately resistant and, Jumbo and Hales Best were susceptible.

The breeding line, U.F. G 508, G509, G510, G511 and G515 showed various levels of resistance to *Alternaria cucumerina, Sphaerotheca fuliginea* and *Pseudoperanospora cubensis* (Halsey, 1980).

Norton and Boyhan (1983) reported that muskmelon breeding line AC 82-37 was found to be highly resistant to *Alternaria cucumerina* followed by PS 164304 and U.F. G511.

In field and laboratory conditions TAM-Uvalde, TAM-Mayan Sweet, Greenflesh Honeydew and breeding lines CAS 2A-17, CAS 2A-20 CAS 2A-21, CAS 2B9 and 2B11 were resistant to *Alternaria cucumerina* (Carmody et al 1985).

2.3.2 Downy mildew

Angelov and Lozanov (1979) studied the resistance of 88 cultivars of musk melon to downy mildew and reported that Seminole was highly resistant and, Perlita, Edisto, Golden Perfection and Georgia -47 were moderately resistant to *Pseudoperanospora cubensis.*

Sambandam *et al.* (1979) screened 26 cucumis forms under natural infection by *Pseudoperanospora cubensis.* They found that Buduma type 1, 2 and 3, Phoonte, Goomukh, Nakkadosa, Ex-2 and the muskmelon cultivars Annamali, Edisto, Harvest Queen, Early Gold, Planters Jumbo and Gulf stream were resistant to downy mildew.

Thomas (1982) evaluated twenty two melon introductions and 14 cantaloupe cultivars for resistance to *Pseudoperanospora cubensis* under epiphytotic conditions. Only 9 plant introductions all from India and 3 cultivars had ≤ 50% leaf loss due to the disease. The most resistant entry was an inbred derivative of PI 124111.

Melon introduction PI 321005, Seminole, Edisto, PI 124112 and PI 124111 (from India) were resistant to downy mildew under field conditions (Zonia *et al.*. 1983).

Jhooty and Bains (1984) reported that two collections of muskmelon and one of wild melon were resistant to downy mildew. Wild melon was cross compatible with muskmelon.

Labeda (1991) studied the resistance of 6 muskmelon lines to 8 isolates of cucurbit downy mildew originating from cucumber. Only line MR-1 was highly resistant with expression of race specificity and genetic heterogeneity.

2.3.3 Powdery mildew

Malinina (1974) reported that among 100 collections of Indian origin tested, K 6205, K 6206, K 5692 and K 5519 were resistant or relatively resistant to *Erysiphe cichoracearum* and *Sphaerotheca fuliginea* under field conditions and are recommended for breeding.

Sowell and Corley (1974) reported that PI 234607, Gorgia 47 and PMR-6 were highly resistant to race-2 of *Sphaerotheca fuliginea.*

Varieties bred in the U.S.A for resistance to *Erysiphae cichoracearum* retained their resistance in Japan. Promising for resistance and fruit quality were Gerogia 47, PMR-5, PMR-6 C398A and their F_1 hybrids of several crosses, the most promising was Hirako-1 later named as Sunrise (Takada *et al.* 1974).

Yuko and Igarashi (1974) bred a line Kurume No2 of muskmelon from a back cross of BC_5 x Sel 108 with BC_5 which was highly resistant to powdery mildew and Fusarium wilt but the flesh was poor and recommended only for breeding or as rootstock.

Waraitch *et al.* (1977) studied the reactions of melon cultivars to *Sphaerotheca fuliginea* under field conditions and on inoculation in the glass house. The cultivar Arka Rajhans, Jacumba, Dulce, PMR-5, Gulf stream and Golden Perfection were field resistant and all but Golden Perfection remained free from symptoms on inoculation.

Frolov (1981) crossed varieties resistant to *Sphaerotheca fuliginea* viz Tabolinka, Kuurme and campo with recommended varieties. The most resistant hybrid was Campo x Desertnaya 5 with a yield of 170c/ha and an ascorbic acid content of 58.6 mg/100g.

Zatkyo (1982) reported that Lira a mid early maturing variety was resistant to *Erysiphe cichoracerum* and *Sphaerotheca fuliginea.*

Gomez-Guillamon and Tores (1989) reported that PI 124112B was resistant to race 1, 2 and 3 of *Sphaerotheca fuliginea* while PMR-6 was resistant to race 1 and 2.

2.3.4 Combined resistance

Swamy *et al* (1980) screened a total of 104 *Cucumis melo* forms, including local forms from six Indian states and forms from 20 foreign countries by stapling infected leaves to healthy leaves. They found that local forms IHR 142, 157, 180, H 190 and H 240 and the Australian form H 226 were resistant to both *Pseudoperanospora cubensis* and *Sphaerotheca fuliginea.*

Thomas and Webb (1982) evolved five breeding lines of muskmelon W1, W3, W4, W5 and W6 from a complex pedigree involving an initial crosses between selection from the wild type *Cucumis melo* PI 180280 and PMR-45. All these five lines are resistant to *P.cubensis, S. fuliginea, A. cucumerina* and Watermelon mosaic virus.

Cohen and Eyal (1987) reported that PI 124111F was a 7^{th} generation selection derived from PI 124111 and is resistant to downy mildew, powdery mildew and Fusarium wilt. PI12411F is a monoecious muskmelon with poor fruit quality, can only be used as breeding line.

Dhiman *et al.* (1995) evaluated four muskmelon genotypes (the open pollinated varieties, MR-12, Hara Madhu, and Punjab Sunheri and the F_1 hybrid, Punjab hybrid) for their reactions to downy mildew, powdery mildew and mosaic. They found that MR-12 was highly resistant to all the diseases.

2.4 GENETICS OF RESISTANCE

In the recent years, knowledge of genetics has been utilized increasingly to breed disease resistant cultivars for increased stable production (Buddenhagen, 1983).

It is important to characterise the genes controlling the resistance mechanism. Such an information is essential to propose breeding strategies for development of disease resistant varieties.

The information on genetics of Alternaria leaf blight, downy mildew and powdery mildew is summerised in this topic.

2.4.1 Alternaria leaf blight.

The information on genetics of Alternaria leaf blight resistance caused by *Alternaria* sp in different crops is summarized in Table 1.

Table 1 Review of genetics of Alternaria leaf blight resistance in different crops

Crop	Resistant line/ cultivar	Pathogen	Gene action	References
1) Muskmelon	Ac 81-37-2 UFG. 511 PI 164756	*Alternaria cucumerina*	Not Clearly defined Mendalian ratio	Boyhan and Norton (1984).
2) Muskmelon	MR-1	*Alternaria cucumerina*	Single dominant gene	Thomas *et al* (1990).
3) Muskmelon	Ac 82-37-2	*Alternaria cucumerina*	Significant additive and dominance effects	Boyhan and Norton (1992).
4) Cucumber	Renish grape	*Alternaria pluriseptata*	Two sensitivity genes together cause hyper sensitivity	Carlsson (1977).
5) Tomato	PI126445	*A. solani*	Dominant polygenes	Gardner (1984)
6) Tomato	PI126445	*A. solani*	Polygene with epistasis	Martin and Heperly (1987)
7) Tomato	87B187	*A. solani*	Additive genes	Maicro *et al.* (1990).
8) Tobacco	IS1043	*A. alternata*	Polygenes	Stavely (1975)
9) Pigeonpea	ICP 7105-12-22-2-2	*A. tenuissina*	Single dominant gene	Singh *et al.* (1988).
10) Safflower	*Carthamus lenatus*	*A. carthami*	Single dominant gene	Heaton and Klisiewicz (1981).

As shown in the Table 1 opinion regarding inheritance of resistance to Alternaria leaf blight differed from crop to crop. It may be due to the genetic makeup of different sources of resistant lines or cultivars also variations in pathogenicity of Alternaria species.

2.4.2 Downy mildew

Reviews on genetics of resistance to downy mildew in different crops is summarised in Table 2.

Apart from this Jenkins (1946) in breeding with cucumber resistant line Puerto Rican resistant source, found that resistance was linked to indeterminate fruiting habit.

Strelnikova *et al.* (1985) found that the genes for resistance to *Pseudoperanospora cubensis* and *Sphaerotheca fuliginea* were linked with the gene D for dull fruit skin in cucumber. However Sazarka *et al.* (1986) stated that only downy mildew resistance was linked with dull skin colour but not the powdery mildew resistance.

2.4.3 Powdery mildew.

Information on genetics of resistance to powdery mildew caused by *Sphaerotheca fuliginea* and *Erysiphe cichoracerum* on different crops is presented in Table 3.

Genetic control varied from single dominant gene to polygenes. Some authors also found the non-Mendalian inheritance with additive and dominance effect with epistatic effects as well.

Table 2 Review of genetics of Downy mildew resistance in different crops

Crop	Resistant line/ cultivar	Pathogen	Gene action	References
1) Muskmelon	PI 124111	*P. cubensis*	Two incompletely dominant genes with cytoplasmic factors	Cohen *et al.* (1985)
2) Muskmelon	MR-1	*P. cubensis*	Two incompletely dominant genes	Thomas *et al* (1988)
3) Muskmelon	PI 124111F	*P. cubensis*	Digenic partial dominance	Kenigsbuch and Cohen (1989)
4) Muskmelon	PI 124112	*P. cubensis*	Two partially dominant genes	Kenigsbuch and Cohen (1992)
5) Cucumber	PI 197087	*P. cubensis*	One or two major genes with one or more minor genes	Burnes and Epps (1954)
6) Cucumber	Poinsette	*P. cubensis*	Single recessive gene	Vliet *et al.* (1977)
7) Cucumber	*Cucumis sativas*	*P. cubensis*	Polygenes	McFerson and Pike (1979).
8) Cucumber	Sadao Rishu	*P. cubensis*	Three major genes exhibiting partial dominance	Pershin *et al* (1988)
9) Cauliflower	Polermo green	*Peranospora parasitica*	Three major genes	Moss *et al* (1988).
10) Sunflower	SI 373	*P cubensis*	More than three dominant genes	Anashchenko (1980).

Table 3 Review of genetics of Powdery mildew resistance in different crops

Crop	Resistant line/ cultivar	Pathogen	Gene action	References
1) Muskmelon	Hales Best	*E.cichoracearum*	Single dominant gene	Jagger *et al.* (1938)
2) Muskmelon	PMR-45 PMR-50	*S.fuliginea* race1 race 2	Single dominant gene Partially dominant and with modifer genes	Bohn and Whitaker (1964)
3) Muskmelon	Georgia-47 C-68	*E.cichoracearum*	Two pairs of incomplete dominant genes	Takoda *et al.* (1975)
4) Muskmelon	PMR-6 Campo	*E.cichoracearum*	Large additive gene effects	Sivakami *et al.* (1979)
5) Muskmelon	PI 124111	*S.fulginea* race 2	Single incomplete dominant gene	Cohen and Cohen (1986)
6) Muskmelon	PI 92417	*S.fulginea* race 1	Single recessive gene	MacCreight *et al.* (1987)
7) Muskmelon	*Cucumis melo*	*S.fuliginea*	Two incompletely dominant genes	Jado and kato (1989)
8) Muskmelon	PI 124111 F	*S.fuliginea* race-1 race-2	Single dominant gene Single partially dominant gene	Kingsbuch and Cohen (1989)
9) Muskmelon	Negro Amarillo	*Spherotheca fuliginea* race-1	Polygenes with dominance and additive effects	Floris and Alvarez (1991)
10) Muskmelon	PMR-45	*S.fuliginea*	Single dominant gene	Epinat *et al* (1993)
	WMR-29 PI 124112	*S.fuliginea* *E.cichoracearum*	Single dominant gene Single dominant gene	

(Contd...)

Crop	Resistant line/ cultivar	Pathogen	Gene action	References
11) Cucumber	*Cucumis sativas*	*E.cichoracearum*	Two duplicate genes	Warid *et al.* (1969)
12) Cucumber	Yamaki	*E.cichoracearum*	Two duplicate recessive genes	Imam *et al.* (1975)
13) Cucumber	Ashley	*E.cichoracearum*	Three completely recessive genes	Robinson (1978)
14) Cucumber	Murata	*S.fuliginea*	Three recessive genes	Yurina (1979)
15) Cucumber	PI 197088	*S.fuliginea*	Resistance is contrlloed by a major rrecessive gene, a dominant gene A and a recessive gene b	Omara (1979)
16) Cucumber	*Cucumis sativas*	*S.fuliginea*	Single dominant gene	Khleborodov (1979)
17) Cucumber	PI 197088	*S.fuliginea*	Single dominant gene	Munger *et al* (1979)
18) Cucumber	Natsufushinari PI 20081518 L 1133	*S.fuliginea* *S.fuliginea* *S.fuliginea*	Two recessive genes Single gene three genes	Hodossi (1980)
19) Cucumber	S 1717	*S.fuliginea*	Single partially dominant gene	El-Jack (1984)

Robinson (1978) observed that tolerance to powdery mildew in cultivar Ashley was completely linked to or pleiotropic with an interveinal chlorosis factor apparently involving magnesium deficiency.

2.5 MECHANISM OF RESISTANCE

Disease resistance is a complex interaction between host and pathogen which apparently varies from disease to disease and crop to crop. Several factors were thought to be associated with the resistance mechanism in plants. Host plant nutrition, external features of plant and biochemical constituents like sugars, phenols and starch were found to influence resistance to Alternaria leaf blight, downy mildew and powdery mildew in muskmelon. After infection there would be a change in enzyme activity and ultra structure of the host tissue. A brief review of literature is presented below on the above aspects.

2.5.1 Host plant nutrition

In studies using sand culture and different levels of nutrition Bains and Jhoothy (1978) observed that disease development was greater on plants grown at one fifth of normal nutrition, and less at high phosphorus, low potash and high nitrogen.

Bains *et al.* (1984) reported that the (Ca+mg)/k ratio was related to the resistance of *Pseudoperanospora cubensis* on melon. Predisposing factors such as host nutrition, prior infection by other pathogen and plant age changed this ratio.

Mahrishi and Sridharan (1988) observed that high doses of phosphorus reduced the incidence of *Pseudoperanospora cubensis* but lower levels together with nitrogen and potash increased the disease incidence. The effect of K was unclear. Of the trace elements zinc and copper reduced the disease significantly.

2.5.2 Plant characters

Cohen (1986) observed that resistance to downy mildew in cucumber variety poinsett resulted both from restriction of fungal growth and prevention of sporangial formation.

Jhoothy *et al.* (1978) observed more infection by *Pseudoperanospora cubensis* on the lower surface of cv. Hara Madhu melon leaves because of the higher number of stomata compared with the upper surface.

Gill and Nandpuri (1978) reported that the more resistant cultivar possessed fewer stomata on both upper and lower leaf surface than those which are susceptible to *P. cubensis.*

Angelov and Petkova (1979) stated that the greatest susceptibility to powdery mildew in cucumber was evident at the cotyledonary stage. Differences in resistance became more apparent at the stage of 3-4 leaves.

The trichome density on leaves was positively correlated with disease resistance. Cheng and Tu (1980) observed no infection on plants of PI 129 which had the maximum trichome density of 4193/cm^2.

Bains and Prakash (1985) observed that resistant cultivars to downy mildew developed fewer and smaller lesions. Resistant lines produced less vegetation, fewer stomata, matured earlier and had higher levels of N, Ca, Mg, Na Cu and Fe and lower Zn and P compared with susceptible ones.

Tests on melon plants in the green house showed the cotyledons to be very susceptible to the pathogen, while the first leaf was relatively resistant. Susceptibility increased up to the 4th to 5th leaf stage and then decreased (Ferriere and Molot, 1988).

2.5.3 Sugars

Hosfall and Dimond (1957) felt that sugars might be responsible in a particular host being infected by a fungal pathogen. They found that pathogens like Uromyces needed higher sugar content while other like *Alternaria* needed low sugar content.

Jindal *et al.* (1979a) observed a higher soluble sugars in the resistant variety than in the susceptible variety when infected with *Sphaerotheca fuliginea.*

Sharma *et al.* (1981) found that leaves of muskmelon cv. Hara Madhu with cucumber mosaic virus and Sphaerotheca fuliginea infections had less total reducing and non-reducing sugars but the starch content was increased.

Kabsch (1982) reported that glucose and fructose in the *Sphaerotheca fuliginea* inoculated cotyledons and primary leaves of cucumber, decreased more than in healthy leaves while phosphorylated derivatives like glucose and fructose-6 phosphates 6 days after inoculation were 40% higher than in the control. Phospoguconate dehydrogenase and hexokinase increased during first stage of pathogenicity then decreased.

Sharma *et al.* (1983) studied the biochemical changes occurring in pea under powdery mildew infection. The data revealed that there was only a slight depletion in total sugar content of leaves.

In chilli, relative amounts of total, reducing and non-reducing sugars increased significantly on infection of cucumber mosaic virus in resistant varieties but in susceptible varieties a subsequent decrease in levels occurred. (Singh and Singh, 1990).

2.5.4 Phenols

Numerous reports have been published on the appearance and accumulation of phenolic compounds in plant tissue in response to infection. Many of these compounds are toxic to certain fungi.

Helal *et al.* (1978) reported that resistance to *Erysiphae cichoracearum* in the variety Poinsett was due to a high concentration of phenols which hindered the infection and a low concentration of sugars which prevented the establishment of pathogen in the host tissue.

Jindal *et al* . (1979b) found that the level of phenols in the susceptible cultivar Hara Madhu increased after infection with *Sphaerotheca fuliginea*, where as that in the resistant cv. PMR-6 declined. The resistance of PMR-6 may be due to the higher amount of flavonol glycoside and chlorogenic acid.

Sharma *et al.* (1981) reported that *Sphaerotheca fuliginea* on phenolics, peroxidase and polyphenol oxidase content in muskmelon and observed that enzyme activity and phenolic content showed an increasing trend in singly or doubly infected plants of cv. Hara Madhu.

Chattopadhyaya (1989) found that Midas, Rc 781 and YRT 3 of rape seed which were resistant to Alternaria blight had slightly higher level of phenols than the susceptible cultivars composite-2 and Varuna.

2.5.5 Peroxidase activity

Reuveni and Bothma (1985) found that the levels of peroxidase activity in leaves of non infected melon plant resistant to Sphaerotheca fuliginea were considerably higher than those in the leaves of susceptible plants. After infection the ratio of peroxidase activity to that in non-infected plants reached a value up to 47.5 in

susceptible plants where as in resistant plants it remained between 1 and 2. In non-infected resistant leaves slowly migrating isozymes were found. Their intensities increased with the time following infection. These isozymes were absent from the susceptible leaves but appeared after the leaves had been infected with S fuliginea.

The levels of peroxidase activity in leaves of non-infected plants resistant to*Pseudoperanospora cubensis* was considerably higher than in the susceptible plants, while the lowest activity was observed in non-infected highly susceptible plants (Reuveni and Karchi, 1987).

Kabsch (1988) studied the enzyme changes taking place in cucumber varieties infected with *Sphaerotheca fuliginea.* Fungal infection resulted in a higher activity of phosphofructokinase and glucose-6-phosphate dehydrogenase in resistant varieties than in susceptible varieties. Activity of phenyl allanine ammonia lyase responsible for phenol synthesis increased greatly after inoculation in the resistant varieties only.

Reuveni *et al* (1990) demonstrated a high correlation ($P<0.05$) between peroxidase activity in test wells containing leaf discs of uninoculated melon plants and resistance to *Pseudoperanospora cubensis.*

Li and Yuan (1991) studied the activity of peroxidase enzyme which increased three times after infection with *Pseudoperanospora cubensis* in cucumber.They also found two new bands of isozymes of peroxidase. They concluded that the higher activity of enzyme and the occurence of new bands of isozymes are probably responsible or play an important role in resistance of cucumber to downy mildew.

Reuveni *et al.* (1992) reported that peroxidase activity increased with time in both resistant and susceptible plants after infection. The ratio of activity in infected to non infected leaves increased over time in the susceptible plants. This ratio however was lower and remain unchanged in the resistant plants.

Yurina *et al* (1993) reported that cucumber varieties tolerant to downy mildew and powdery mildew had higher activity of peroxidase enzyme than the susceptible ones. Peroxidase activity rose after infection to a greater extent in the tolerant variety than in susceptible one. They suggested that peroxidase activity could be used as means of screening for resistance without preliminary inoculation.

2.5.6 Histopathology

Rubin (1975) reported that the main role in resisting infection by *Erysiphae cichoracearum* on cucumber belonged to the protein synthesising system and genetically connected to morphological structures and catalytic system.

Cohen *et al.* (1989) studied the ultra structure of *pseudoperanospora cubensis* in muskmelon genotypes susceptible and resistant to downy mildew. They found that sporulation of PI 124111F a resistant line was extremely limited compared with conspicuous sporulation on Ananas Yokneam a susceptible line. In both the fungus produced intercellular hyphae rich in β-1-3 glucose. The haustoria had induced only minor chemical and ultrastructural changes in the cytoplasm and/or walls of Ananas Yokneam, 144 hours after infection, whereas in contrast, major changes were observed in cells of PI as early as 20 hours after inoculation which included a heavy deposition of paramural, layered, callose like material along the inner surface of host cell walls, enrichment of host cell walls with lignin like material and encasement of haustoria with heavy deposits of callose-like materials. The containment of host cell and haustoria by callose and lignin like material in resistant plants may interrupt the flow of nutrients from and into the invaded host cells.

Schlosser (1990) described the mechanism of resistance in cucumber to powdery mildew. He stated that resistance was linked to the antogenetic stage of epidermal cells. The epidermal cells become increasingly resistant with age due to progressive depletion of cytoplasm and concomitant vacuolization, and to increasing numbers of papillae which inhibited fungal penetration.

Li *et al* (1991) reported that in cucumber when resistant cultivars were infected, infected cells rapidly broke down and both cell and fungus died. The mesophyll cells between infected spots multiplied rapidly. Number of chloroplast decreased and membrane systems were destroyed, accompanied by cell wall thickening. A few small necrosis were visible on the leaf surface. In contrast to this in susceptible lines many hyphae penetrated the mesophyll and at maturity produced number of sporangiophore and sporangia. When cells died as a result of infection, adjacent cells were easily infected. Numerous large necrotic spots appeared coalescing to form large lesions.

Ma and Cui (1995) found that faster necrosis of cells (24 hours) after infection with *Pseudoperanospora cubensis* focus in resistant source compared to susceptible source (72 hours) which resulted in fewer haustoria development on host cell was responsible for resistance to downy mildew.

MATERIAL AND METHODS

MATERIALS AND METHODS

The experiments pertaining to genetics of resistance to Alternaria leaf blight, downy mildew and powdery mildew in muskmelon were conducted at the Division of Vegetable Crops, Indian Institute of Horticulture Research (I.I.H.R), Hessaraghatta, Bangalore during 1994-96. The experimental site is situated at 13° 58" north latitude and 78° east longitude and at an elevation of 890 meters above mean sea level. Materials used and methods followed during the period of experimentation are described below.

3.1 MATERIALS

The materials used in present investigations comprised of 5 muskmelon breeding lines belonging to *Cucumis melo*. The seed materials were supplied from the germplasm maintained at the Division of Vegetable Crops, Indian Institute of Horticulture Research, Hessaraghatta, Bangalore. The accession numbers and description of genotypes are presented in Table 4.

3.2 METHODS

3.2.1 Genetics of Alternaria leaf blight, Downy mildew, and Powdery mildew resistance.

3.2.1.1 Development of F_1, F_2 and back cross progenies

The resistant lines IIHR 352a, IIHR 352b, IIHR 352c and IIHR 190-1, and susceptible variety Arka Jeet were used in the hybridization program. The parents were sown in the month of December 1994, and maintained with proper care. Crossing was started in the month of January 1995. Arka Jeet was taken as female parent and resistant lines as male parents.

Plate 1 Resistant line IIHR 352a

Plate 2 Resistant line IIHR 352b


352-12-1

Plate 3 Resistant line IIHR 352c

Plate 4 Resistant line IIHR 190-1


352-1-2-3


190-1

Plate 5 Susceptible variety Arka Jeet

Plate 6 Downy mildew on susceptible variety Arka Jeet


ARKA JEET


DOWNY MILDEW

Table 4 . List of breeding lines/varieties used in the crossing program and their accession numbers , description and source

Sl. No.	Breeding line/variety	Accession No.	Description	Source
1	Arka Jeet	-	Andromonoecious variety with good horticultural qualities but susceptible to Alternaria leaf blight downy mildew and Powdery mildew	IIHR Bangalore
2	IIHR 352a	352-1-2-1-1	Monoecious line resistant to Alternaria leaf blight, downy mildew and powdery mildew	Rajasthan
3	IIHR 352b	352-1-2-1	Monoecious line resistant to Alternaria leaf blight, downy mildew and powdery mildew	Rajasthan
4	IIHR 352c	352-1-2-3	Monoecious line resistant to Alternaria leaf blight, downy mildew and powdery mildew	Rajasthan
5	IIHR190-1	190-1	Andromonoecious line resistant to Alternaria leaf blight, downy mildew and powedery mildew	Uttar Pradesh

Female flowers on female parent were emasculated a day prior to pollination by removing the stamens with the help of forceps and bagged. Male flowers of male parents were tied at the tip a day before anthesis. Pollination of female flower with male parents were carried out the next day. Female flowers, after crossing were properly labelled and covered with butter paper bags. The crossing was carried out to get sufficient F_1 seeds of four crosses viz A. Jeet X IIHR 352a, A. Jeet X IIHR 352b, A. Jeet X IIHR 352c- and A Jeet X IIHR 190-1.

In the next season during April 1995 all four F_1 hybrids and parents were sown in the crossing block. At the time of flowering, F_1 flowers were selfed to get F_2 seeds. In the same crop the F_1 s were crossed to the respective resistant parents to get BC_1 generations Viz. (A Jeet X IIHR 352a) X IIHR 352a, (A. Jeet X IIHR 352b) X IIHR 352b, (A. Jeet X IIHR 352c) X IIHR 352c and (A. Jeet X IIHR190-1) X IIHR 190-1. Similarly F_1 s were crossed to susceptible parent to get BC_2 generation viz (A. Jeet X IIHR 352a) X A. Jeet (A. Jeet X IIHR 352b) X A. Jeet, (A Jeet X IIHR 352c) X A. Jeet and (A. Jeet X IIHR 190-1) X A.Jeet. In all the above crosses, ripe fruits were harvested, seeds were separated, washed to separate mucilage and pulp, dried under shade and packed.

3.2.1.2 Evaluation of segregating populations and parents for resistance to Alternaria leaf blight and downy mildew.

Materials used in this experiment to study the inheritance of Alternaria leaf blight and downy mildew resistance included six generations viz P_1, P_2, F_1, F_2, B_1 and B_2 of the crosses of A. Jeet X IIHR 352a and A. Jeet X IIHR 190-1. Experimental material comprising of six generations of each crosses was laid out in randomized block design with four replications during October 1995. The number of plants consisted of 50 each in P_1, P_2, and F_1, 250 in F_2 and 100 in backcross generations. Susceptible cultivar Arka Jeet was raised along the border as well as after every five rows to maintain uniform spread of disease.

3.2.1.2.1 Cultural Practices.

Land was ploughed and harrowed to bring the soil to fine tilth. About 20 tons of well rotten FYM per hectare was incorporated 10 days prior to sowing. Sowing channels were prepared at a distance of 1.5 meters apart. Chemical fertilizers supplying 50 kg N, 25 kg P_2O_5 and 50 kg K_2O were incorporated into the furrows and well irrigated a day prior to sowing. Seeds of parents, F_1 s, F_2 s, B_1 and B_2 population were sown in the ridges at a distance of 60 cm apart and covered with a thin layer of soil. After germination seedlings were thinned to 2 seedlings per hill. Remaining 50 kg N per hectare was incorporated a month after sowing and earthingup was carried out. Recommended insecticidal sprays were given to control the serious pests like red pumpkin beetles, aphids and mites.

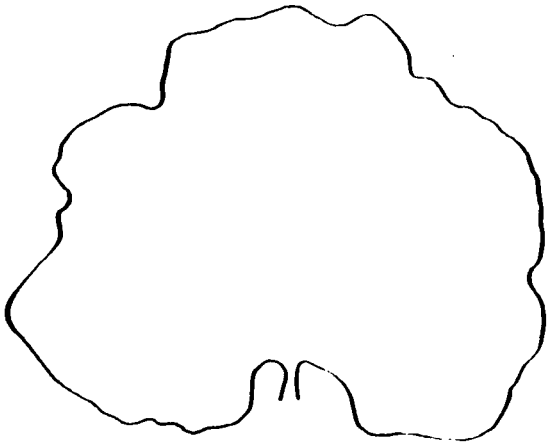
3.2.1.2.2 Disease assessment.

The plant disease was assessed in all the progenies when the Alternaria leaf blight and downy mildew were severe on susceptible parent Arka Jeet. Graphs were prepared (Fig. 1) for different levels of disease intensity on leaves and all the leaves in each plant were compared with the standard graphs and assigned to corresponding groups. The 0 to 5 scale was used for estimating the intensity of Alternaria leaf blight and downy mildew among different progenies.

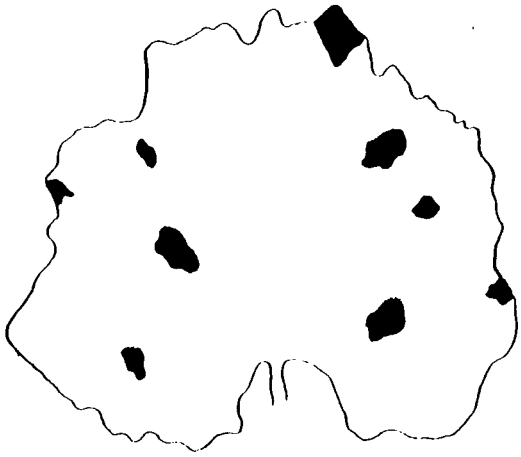
Grade	Percent leaf area infected
0	0
1	1-5%
2	6-10%
3	11-20%
4	21-30%
5	>30%

During the next season, in April 1996 six generations of crosses A. Jeet X IIHR 352a, A. Jeet X IIHR 352b, A. Jeet X IIHR 352c and A. Jeet X IIHR 190-1 were evaluated for resistance to Alternaria leaf blight and downy mildew

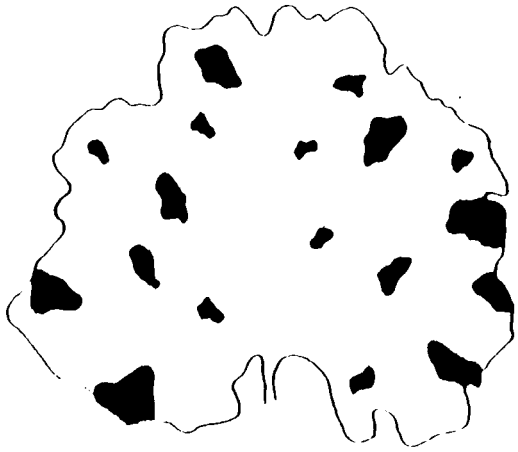
Fig. 1. Disease assessment scales for Alternaria leaf blight and downy mildew.



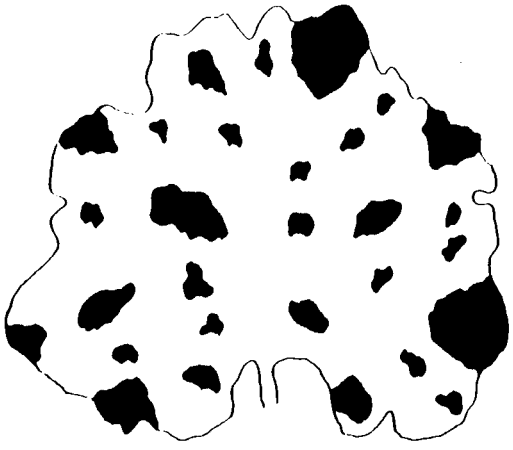
Scale 0



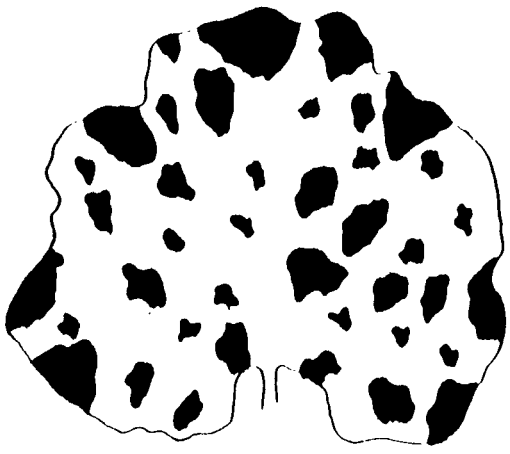
Scale 1



Scale 2



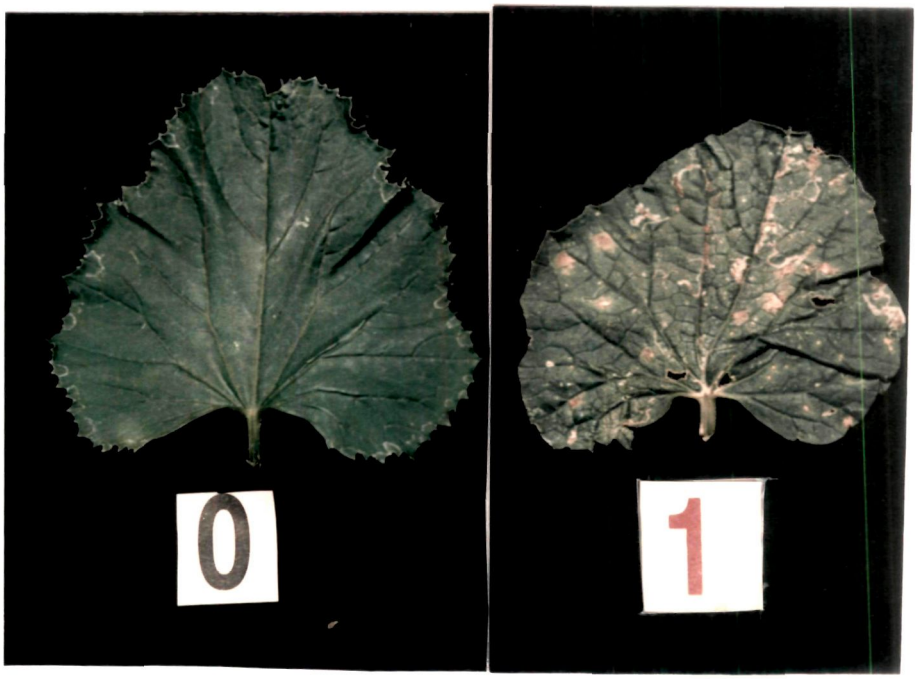
Scale 3



Scale 4

Plate 7 Downy mildew and Alternaria leaf blight assessment scale 0 and 1

Plate 8 Downy mildew and Alternaria leaf blight assessment scale 2 and 3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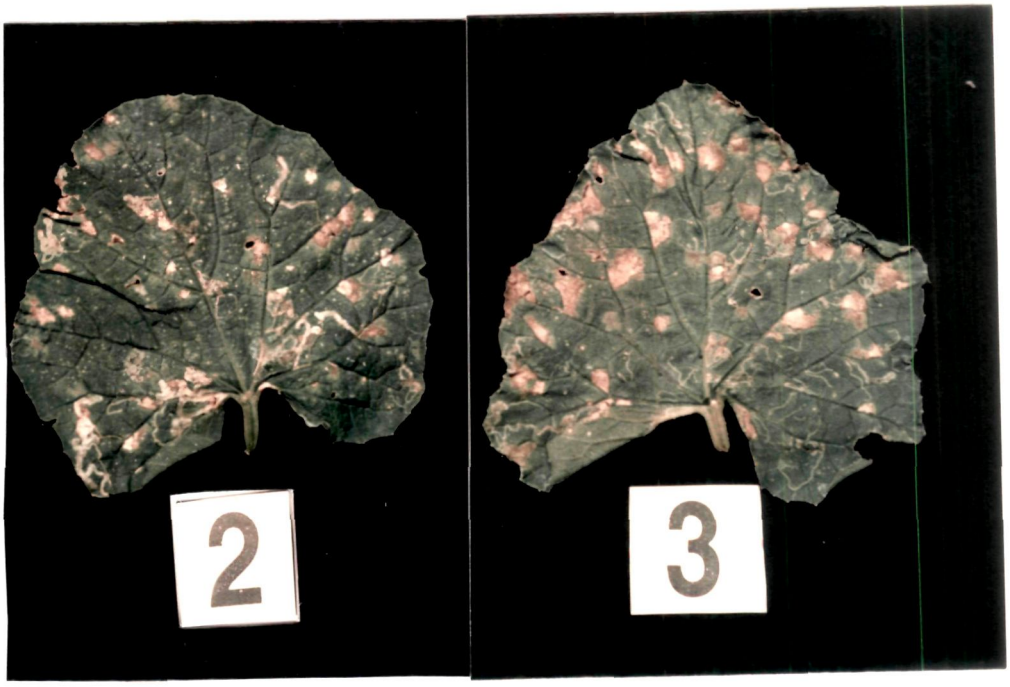
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Plate 9 Downy mildew and Alternaria leaf blight assessment scale 4 and 5


4
5

diseases. The methods adopted for raising crop and scoring for disease incidence were similar to those followed in the earlier experiment. Per cent disease index (PDI) was calculated using the formula mentioned in section 3.2.1.4.

3.2.1.3 Evaluation of parents and segregating populations for resistance to powdery mildew.

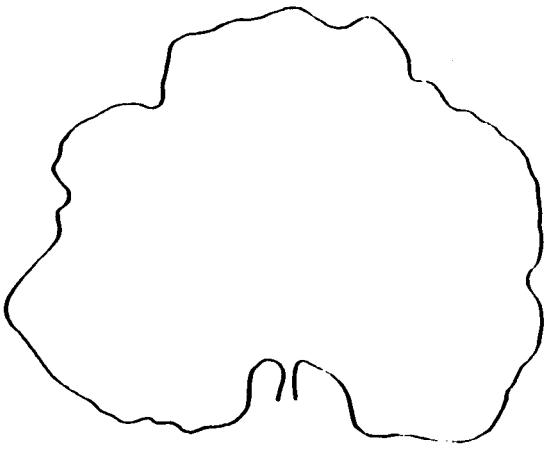
Experimental material comprising of P_1, P_2, F_1, F_2, B_1 and B_2 of crosses A. Jeet X IIHR 352a, A. Jeet X IIHR 352b, A. Jeet X IIHR 352 X and A. Jeet X IIHR 190-1 were sown in a randomized complete block design with four replications during October 1996. Susceptible cultivar Arka Jeet was raised along the borders and after every five rows to maintain the strength and uniformity of inoculum. Crop was well maintained by following methods described in the earlier experiment.

3.2.1.3.1 Disease inoculation and scoring.

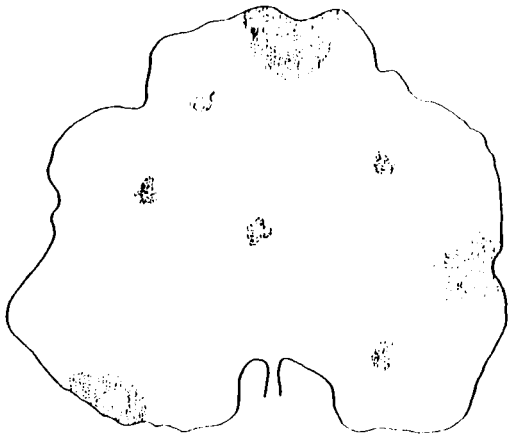
When the plants were 45-50 days old, the leaves of healthy plants were stapled with powdery mildew infected leaves. This method was proposed by Swamy *et al* (1980). A second inoculation was given 15 days after the first inoculation. This type of inoculation helped for the uniform spread of disease in the plant population. Powdery mildew was evaluated using a 0 to 10 scale for which separate graphs were prepared for comparison (Fig. 2). The leaves were assigned to the deserved groups. Following was the scale used for assessing disease incidence in the population

Grade	Percent leaf area infected
0	0
1	0-10%
2	11-20%
3	21-30%
4	31-40%
5	41-50%
6	51-60%

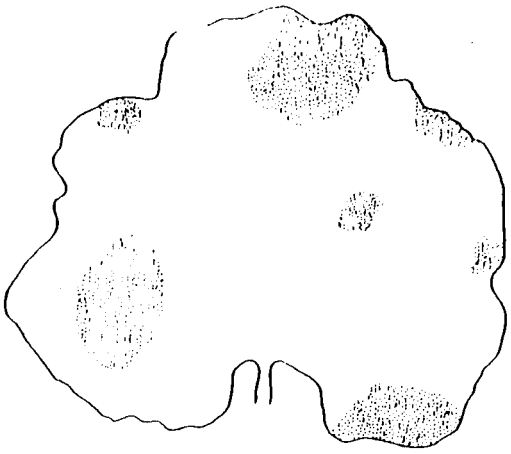
Fig. 2. Disease assessment scales for powdery mildew.



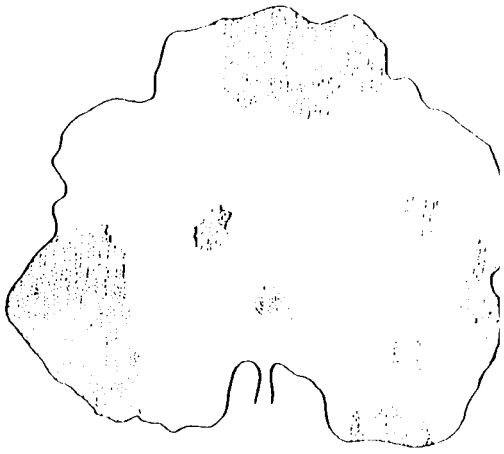
Scale 0



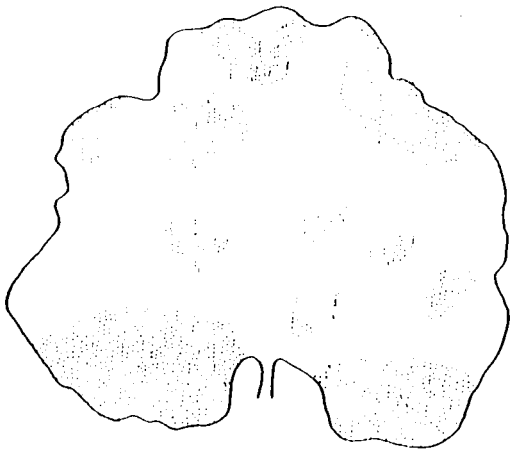
Scale 1



Scale 2



Scale 3



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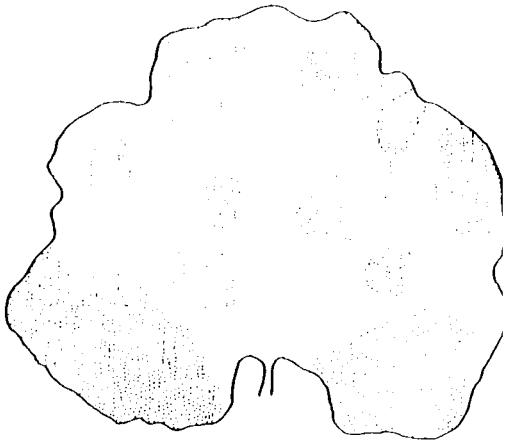

Scale 5

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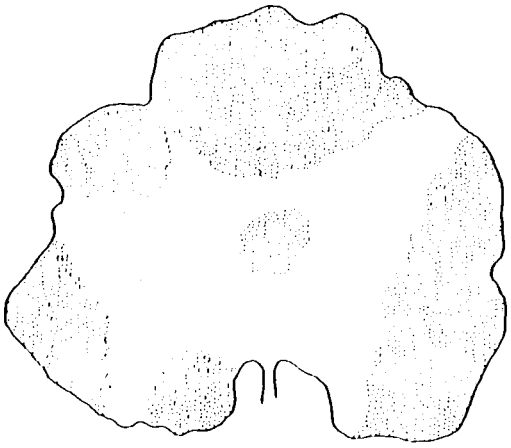
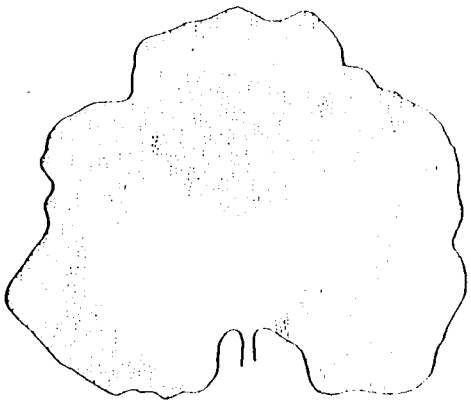


Scale 6



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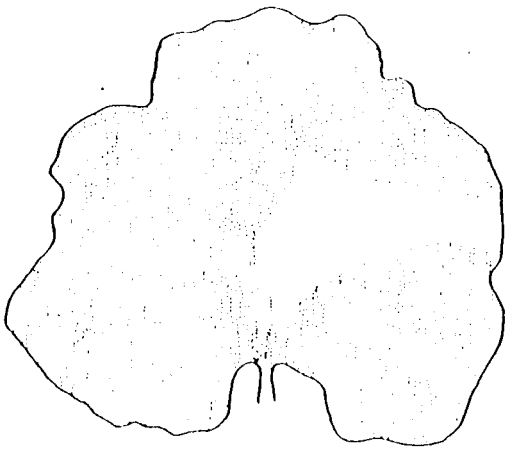
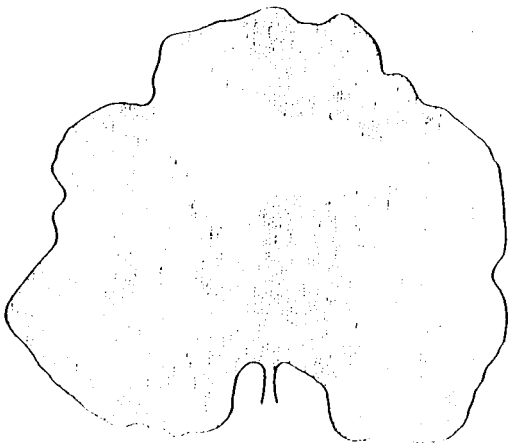


Scale 8



Scale 9

Plate 10 Powdery mildew assessment scale 0 and 1

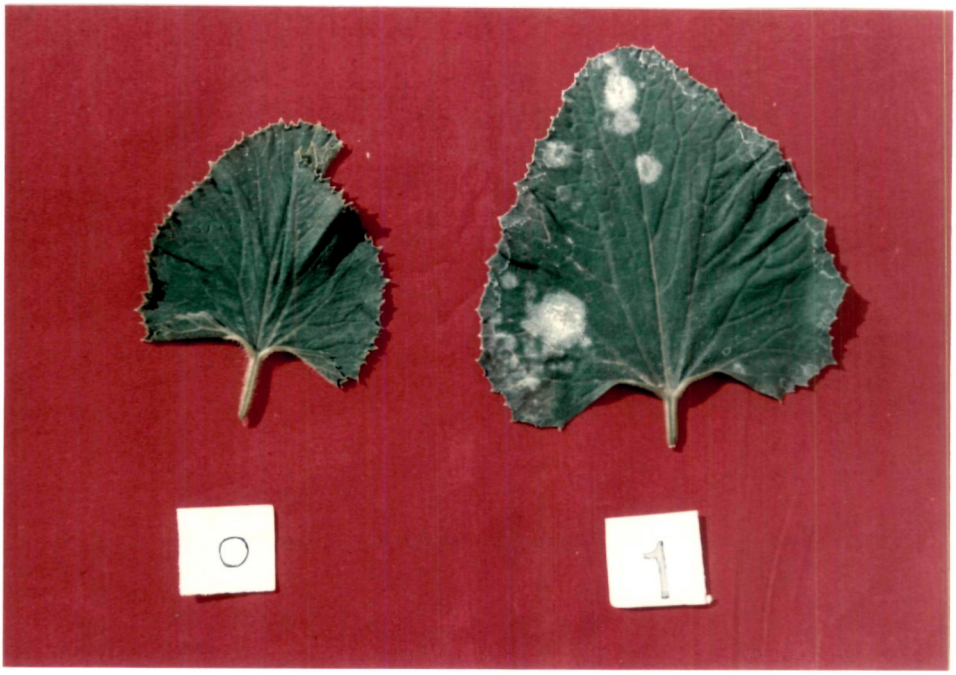
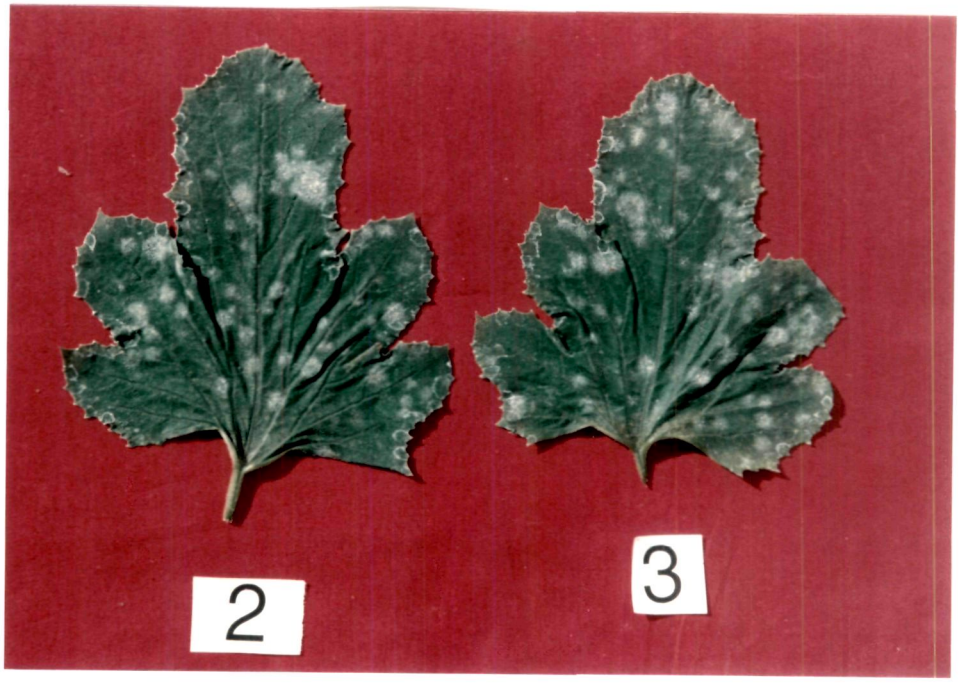

0
1

Plate 11 Powdery mildew assessment scale 2 and 3

Plate 12 Powdery mildew assessment scale 4 and 5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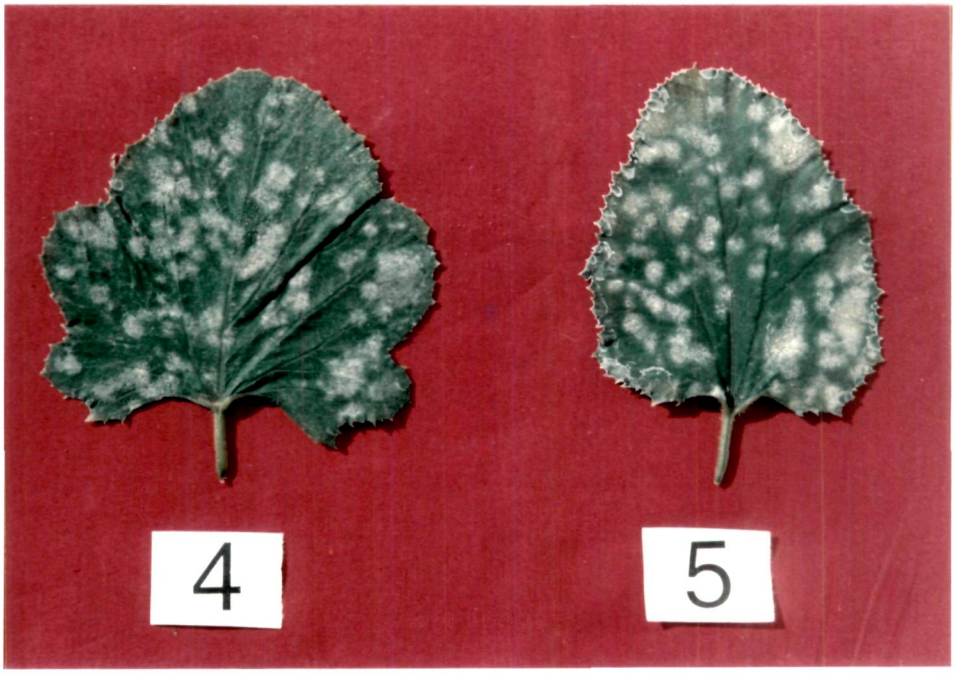
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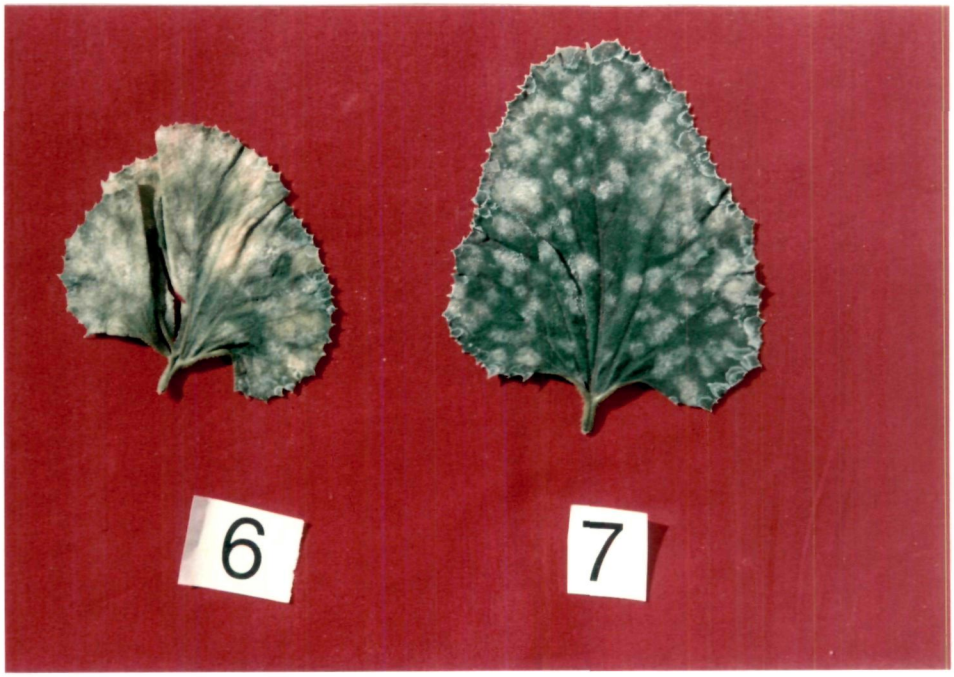
Plate 13 Powdery mildew assessment scale 6 and 7

Plate 14 Powdery mildew assessment scale 8 and 9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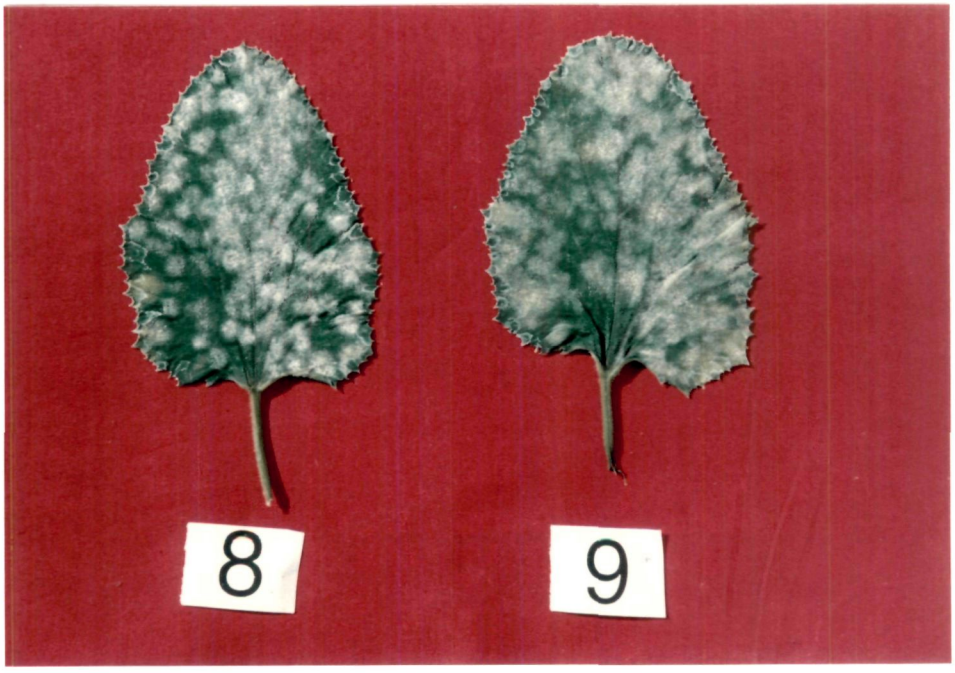

8
9

7	61-70%
8	71-80%
9	81-90%
10	91-100%

3.2.1.4 Calculation of per cent disease index (PDI) and classification of parents and progenies

Per cent Disease Index (PDI) was calculated for every plant using the formula

$$P.D.I. = \frac{\text{Sum of numerical values}}{\text{Number of leaves greaded X maximum rating}} \text{ X } 100$$

After calculating PDI for every plant in all the generations, the population was categorised in to four groups as resistant, moderately resistant, susceptible and highly susceptible based on their PDI values.

PDI	Group
0-20	Resistant
21-40	Moderately resistant
41-60	Susceptible
> 61	Highly susceptible.

3.2.2 Disease developmental study

3.2.2.1 Disease developmental study of Alternaria leaf blight and downy mildew in Arka Jeet

Commercial variety and susceptible parent Arka Jeet was used for the disease developmental study of Alternaria leaf blight and downy mildew. Seeds of suscep-

tible parent Arka Ject were sown in a completely randomized block design during october 1995. Five plants in each replication were tagged to record observations. Recommended cultural operations were carried out to maintain the crop. Disease assessment was made on the tagged plants at an interval of 10 days using 0-5 scale. Data on daily maximum and minimum temperatures, relative humidity I (morning) and II (evening) and rainfall were collected from the materiological department of Indian Institute of Horticultural Research Hessaraghatta, Bangalore.

3.2.2.2 Disease developmental study of powdery mildew in susceptible variety Arka Jeet.

Susceptible variety Arka Jeet was sown in randomized block design with four replications during october 1996. Recommended intercultural operations were carried out. Five plants in each replications were tagged for continuous observations. Disease on the tagged plants were recorded with an interval of 10 days. Daily information on maximum and minimum temperatures, relative humidity I (morning) and II (evening) and rainfall were collected from the meteriological department of IIHR, Hessaraghatta Bangalore.

3.2.3 DISEASE PROGRESS STUDY

3.2.3.1 Disease progress study of Alternaria leaf blight and downy mildew in resistant and susceptible parent

Two resistant parents (IIHR 352a and IIHR 190-1) and the susceptible variety Arka Jeet were used for disease progress study. Seeds of the parents were sown in a completley randomized block design during october 1995. Five plants in each replication in each parent were tagged to record observations. Recommended cultural operations were carried out to maintain the crop. Disease assessment was made on the tagged plants at an interval of 10 days using 0-5 scale.

3.2.3.2 Disease progress study of powdery mildew in resistant and susceptible parent

Two resistant parents (IIHR 352a and IIHR 190-1) and the susceptible variety Arka Jeet were used for disease progress study. Seeds of the parents were sown in a completley randomized block design during october 1996. Five plants in each replication in each parent were tagged to record observations. Recommended cultural operations were carried out to maintain the crop. Disease assessment was made on the tagged plants at an interval of 10 days using 0-10 scale.

3.2.4 SPORULATION STUDY

Leaves of Alternaria leaf blight, downy mildew and powdery mildew infection were collected from infected plants of resistant and susceptible lines. In each case one square cm. of the infected area was cut and crushed in 1 ml of distilled water. One drop of the above solution was taken on the haemocytometer and counts of oospores and conidia were recorded. The experiment was carried out in a completely randomized design with 5 replication.

The concentration of fungal spores was determined with the aid of Haemocytometer using the formula

$$\text{Concentration (Spores / ml)} = \frac{\text{Average no. of spores X 4 X } 10^6}{400}$$

3.2.5 BIOCHEMICAL ANALYSIS

3.2.5.1 Collection of leaf samples

Uninfected and infected leaf samples were collected from the resistant and

susceptible parents separately. Samples were brought to laboratory and dried in hot air over for two days. The dried leaf samples were powdered in a grinder and packed in butter paper bags for further biochemical analysis. All the bio-chemical estimation experiments were carried out in completely randomized design with 4 replication.

3.2.5.2 Extraction of leaf samples in alcohol.

Two grams of dried leaf powder was taken in a test tube and 10ml of ethyl alcohol was added to the powder and boiled over hot water bath for 5-10 minutes. Extract was filtered through Whatman No. 41 filter paper, the extraction was repeated for three times. The final volume of filtered alcohol extract was noted. Before using alcohol extract for biochemical analysis, alcohol was evaporated on a hot water bath till alcoholic smell disappears.

3.2.5.3 Estimation of total sugars.

Comparative estimation of total sugars in resistant and susceptible parents were done by using Phenolsulphuric acid method.

Leaf sample was extracted with alcohol as explained earlier. Exactly 0.1ml of the alcohol evaporated plant extract was taken in a test tube and 1 ml of phenol solution was added to each tube. After this, 5 ml of 96% sulphuric acid was added and shaken well. After 10 minutes, test tubes were shaken well and placed on a water bath at 30° C for 20 minutes. The absorbance of the colour developed was measured at 490 nm in a spectrophotometer.

Standard curve was prepared by using glucose at various dilutions. (0.2, 0.4, 0.6, 0.8 and 1.0 mg). The absorbance at 490 nm for standard solution was measured. This standard curve was used to get total sugar content of samples in milligrams.

3.2.5.4 Estimation of reducing sugars in the resistant and susceptible parents.

Reducing sugars of the samples was estimated by Nelson-Somogyi method (Nelson, 1944)

Exactly 0.2 ml of the alcohol evaporated leaf extract was taken in a test tube and volume was made up to 2.0ml with distilled water. A blank was run with out plant sample. One ml of copper tartarate reagent was added to each tube. These tubes were placed on hot water bath for 10 minutes. After this, the tubes were cooled and one ml. of arsenomolybdic acid reagent was added to all tubes. Volume was made up to 10 ml in all tubes with distilled water and absorbance of blue colour was noted at 620 nm after 10 minutes.

Standard curve was prepared in the similar way using 0.2, 0.4, 0.6, 0.8 and 1.0 mg of glucose. The reducing sugar content of samples were measured by comparing to the standard curve.

3.2.5.6 Estimation of starch in the resistant and susceptible parents.

Anthrone reagent method was used to measure the starch content of leaf samples of resistant and susceptible parents.

Exactly 0.1g of the leaf powder sample was homogenized with 80% ethanol to remove sugars. The solution was centrifuged at 10,000 rpm and residue was retained. To the residue five ml of distilled water and 6.5ml of 52% perchloric acid was added. This was extracted at 0^{0} C for 20 minutes and supernatant was saved. Extraction was repeated using fresh perchloric acid and the supernatants volume was made up to 100 ml with perchloric acid. Exactly 0.1ml of the supernatant was taken in a test tube to which 4 ml of anthrone reagent was added. The mixture was boiled for 8 minutes in a boiling water bath and the absorbance of green colour was recorded at 630 nm.

A standard curve was developed by using glucose at 0.2, 0.4, 0.6, 0.8 and 1.0 mg concentrations. The glucose content in the sample was calculated by using standard graph. The glucose value was multiplied by a factor 0.9 to arrive at the starch content in milligrams.

3.2.5.7 Estimation of total phenols in resistant and susceptible parents.

Folin-Ciocalteu reagent method was followed to estimate total phenols in the plant samples. (Anon, 1970).

One ml of the alcohol evaporated plant extract was taken in a test tube and one ml of Folin-Ciocalteu, reagent was added to the test tube followed by 2 ml of Na_2CO_3 solution and heated in a boiling water bath exactly for one minute. The tube was cooled and diluted to 25 ml with distilled water and the absorbance was measured at 650 nm. A standard curve was made from different concentrations of catechol. Total phenol content was calculated by comparing absorbance value with standard curve.

3.2.6 STATISTICAL ANALYSIS

Analysis of variance was carried out for Per cent Disease Index (PDI), biochemical compositions separately using the method proposed by Panse and Sukhateme (1986).

3.2.6.1 Components of gene action through six generation mean analysis.

The means of all the six generations were analysed by the method proposed by Hayman (1958) to obtain information on the nature of the gene action governing the character under study. The notations used for various gene effects were those given by Hayman (1958) which are as follows.

Gene effects	Notations
Mean	$\hat{m}$
Additive	$\hat{d}$
Dominance	$\hat{h}$
Additive x Additive	$\hat{i}$
Additive x Dominance	$\hat{j}$
Dominance x Dominance	$\hat{l}$

Using the following equations the estimate of $\hat{m}$, $\hat{d}$, $\hat{h}$, $\hat{i}$, $\hat{j}$ and $\hat{l}$ were estimated.

$$\hat{m} = \bar{F}_2$$

$$\hat{d} = \bar{B}_1 - \bar{B}_2$$

$$\hat{h} = \bar{F}_1 + 2\bar{B}_1 + 2\bar{B}_2 - 1/2\ \bar{P}_1 - 1/2\ \bar{P}_2 - 4\bar{F}_2$$

$$\hat{i} = 2\bar{B}_1 + 2\bar{B}_2 - 4\bar{F}_2$$

$$\hat{j} = \bar{B}_1 - \bar{B}_2 - 1/2\bar{P}_1 - 1/2\bar{P}_2$$

$$\hat{l} = \bar{P}_1 + \bar{P}_2 + 2\bar{F}_1 + 4\bar{F}_2 - 4\bar{B}_1 - 4\bar{B}_2$$

The variance of estimates of gene were obtained as follows.

$$V\hat{m} = V\bar{F}_2$$

$$V\hat{d} = V\bar{B}_1 + V\bar{B}_2$$

$$V\hat{h} = V\bar{F}_1 + 16V\bar{F}_2 + 1/4(V\bar{P}_1 + V\bar{P}_2) + 4(V\bar{B}_1 + V\bar{B}_2)$$

$$V\hat{i} = 4\,(V\bar{B}_1 + V\bar{B}_2) + 16V\bar{F}_2$$

$$V\hat{j} = V\bar{B}_1 + V\bar{B}_2 + 1/4\,(V\bar{P}_1 + V\bar{P}_2)$$

$$V\hat{l} = V\bar{P}_1 + V\bar{P}_2 + 4V\bar{F}_1 + 16\,(V\bar{F}_2 + V\bar{B}_1 + V\bar{B}_2)$$

Where $V\hat{m}$, $V\hat{d}$, $V\hat{h}$, $V\hat{i}$, $V\hat{j}$ and $V\hat{l}$ were the variance of the means of $\hat{m}$, $\hat{d}$, $\hat{h}$, $\hat{i}$, $\hat{j}$ and $\hat{l}$ respectively. $V\bar{P}_1$, $V\bar{P}_2$, $V\bar{F}_1$, $V\bar{F}_2$, $V\bar{B}_1$ and $V\bar{B}_2$

were the variances of means of different generations. Square roots of the variances of these estimates provided standard errors for testing the significance of corresponding estimates.

3.2.6.2 Estimation of genetic parameters

The components of variances namely phenotypic genotype and environmental variances, phenotypic and genotypic coefficents of variations were calculated using the following equation.

$$Vp = D + H + E$$

$$Vg = D + H$$

where Vp = phenotypic variance

Vg = genotypic vaiance

$$D = 2\ (2\ VF_2 - (VB_1 + VB_2))$$

$$H = 4\ (VF_2 - 1/2\ D - E)$$

$$E = (VP_1 + VP_2 + VF_1) / 3$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{(\text{Genotypic variance})^{1/2}}{\text{General mean of the population}} \text{X100}$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{(\text{Phenotypic variance})^{1/2}}{\text{General mean of the population}} \text{X 100}$$

3.2.6.3 Heritability

Heritability in broad sense (h^2b) was calculated as the ratio of genotype variance to total variance

$$h^2b\ (\%) = (G.V/P.V)\ X\ 100$$

Heritability in narrow sense (h^2n) was calculated as a ratio of additive variance (AV) to total variance (PV)

$$h^2n\ (\%) = (AV/PV)\ X\ 100$$

3.2.6.4 Genetic advance (GA)

Genetic advance was calculated using the following formula

$$GA = (\text{Phenotypic variance})^{1/2}\ X\ h^2\ X\ K$$

where K = selection differential at 5 % selection intensity

h^2 = Heritability

3.2.6.5 Genetic gain (Gg)

Genetic gain = (Genetic advance/Population mean) X 100

3.2.6.6 Correlation coefficients

Correlation coefficients between different characters were calculated by using the formula

$$r = Cov\ X\ Y/(Vx.\ Vy)^{1/2}$$

The significance was tested against "r" values given by Fisher and Yates (1963)

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

Experiments were conducted to study the genetics of Alternaria leaf blight, downy mildew and powdery mildew in muskmelon using resistant parents IIHR 352a, IIHR 352b, IIHR 352c and IIHR 190-1 and susceptible parent Arka Jeet. Disease developmental study and biochemical studies pertaining to disease resistance were also conducted using resistant and susceptible lines. The results obtained are presented in this chapter.

4.1 GENETICS OF ALTERNARIA LEAF BLIGHT IN MUSK MELON.

4.1.1 Analysis of variance

The mean performance and analysis of variance of six generations (P_1, P_2, F_1,F_2,BC_1, BC_2) in the two sets viz A. Jeet X IIHR 352a and A. Jeet X IIHR 190-1 for per cent disease index of Alternaria leaf blight was studied for two seasons (october 1995 and April 1996). Other two crosses viz A.Jeet X IIHR 352b and A.Jeet X IIHR 352c were evaluated only in April 1996. The results of these studies are presented in Table 5 and 6.

4.1.1.1 Six generations of the cross A.Jeet X IIHR 352a during october 1995.

The analysis of variance displayed significant difference among the six generations for PDI of Alternaria leaf blight (Table 5).

The resistant parent IIHR 352a had the least PDI (5.01) which was on par with the PDI of F1 (7.66). The susceptible variety Arka Jeet had the maximum PDI of 66.78 which was significantly higher than other generations. The F2 (30.17), B1 (21.98) and B2 (34.84) had significantly higher PDI compared with the resistant parent and significantly lower PDI compared to susceptible parent, Arka Jeet.

Table 5 Generation means and their analysis of variance for Alternaria leaf blight (PDI) in the six generarions of different crosses during october 1995

Generation	Per cent disease index of crosses involving	
	A.Jeet x 352a	A.Jeet x 190-1
P_1	5.01[a]	2.22[a]
P_2	66.78[e]	66.78[d]
F_1	7.66[a]	4.37[a]
F_2	30.17[c]	26.69[b]
B_1	21.98[b]	5.68[a]
B_2	34.84[d]	31.65[c]
F test	**	**
C.D at 5%	3.61	3.19
S. Em	1.20	1.06

Table 6 Geneation means and their analysis of variance for Alternaria leaf blight (PDI) in the six generation of different crosses during April 1996

	Crosses			
Generation	A.Jeet x 352a	A.Jeet x 352b	A.Jeet x 352c	A.Jeet x 190-1
P_1	6.80[a]	6.44[a]	6.48[a]	5.62[a]
P_2	69.10[e]	68.75[e]	68.20[e]	68.81[d]
F_1	8.09[a]	6.80[a]	8.38[a]	7.08[a]
F_2	31.68[c]	27.32[c]	27.61[c]	27.32[b]
B_1	13.41[b]	10.64[b]	10.77[b]	7.78[a]
B_2	42.62[d]	37.89[d]	41.74[d]	29.28[c]
F test	**	**	**	**
C.D at 5%	3.97	2.30	4.56	3.71
S. Em	1.32	0.76	1.51	1.23

4.1.1.2 Six generations of the cross Arka Jeet X IIHR 190-1 during October 1995.

During October 1995, Arka Jeet had the maximum PDI for Alternaria leaf blight as indicated by the significantly higher PDI of 66.78 per cent. Resistant parent IIHR 190-1 had the least PDI (2.22) which was on par with F_1 (4.37) and B_1 (5.68) generations. The remaining F_2 and B_2 generations differed significantly with each other (Table 5).

4.1.1.3 Six generations of the cross Arka Jeet X IIHR 352a during April 1996.

The resistant parent IIHR 352a had the least intensity of Alternaria leaf blight with a PDI of 6.8 which was on par with F1 (8.09) generation. The F_2, B_1 and B_2 generations differed significantly from among themselves for PDI. Susceptible variety Arka Jeet had the highest PDI of 69.10 which differed significantly from all other generations (Table 6).

4.1.1.4 Six generations of the cross Arka Jeet X IIHR 352b during April 1996.

Highest PDI (68.75) for Alternaria leaf blight was observed in tthe susceptible parent Arka Jeet. The F_2, B_1 and B_2 generations had intermediate PDI (27.32, 10.64 and 37.89 respectively) which were significantly different from parents and F_1. Resistant parent IIHR 352b had the minimum PDI for Alternaria leaf blight (6.44) which was on par with the PDI of F_1 (Table 6).

4.1.1.5 Six generations of the cross A.Jeet X IIHR 352c during April 1996

During April 1996, resistant parent IIHR352c had the minimum disease intensity with the PDI of 6.48 per cent which was on par with the PDI of F_1 and B_1 generations. F_2 and B2 generations had significantly higher PDI compared to

resistant parent and F1. Susceptible variety Arka Jeet had the highest Alternaria leaf blight with a PDI of 68.20 which differed significantly from other generations.

4.1.1.6 Six generations of the cross Arka Jeet X IIHR 190-1 during April 1996.

The resistant parent IIHR 190-1 had the least infection with Alternaria leaf blight as indicated by the lowest PDI of 5.62 which was on par with F_1 and B_1 generations. The PDI of F_2 and B_2 were significantly higher than resistant parent and F_1 but on par with each other. Arka Jeet, the susceptible parent had significantly higher PDI (68.81) compared to all other generations (Table 6).

The overall result of analysis of variance revealed that during october 1995, resistant parent IIHR 190-1 had the least Alternaria leaf blight intensity with a PDI of 2.2 per cent followed by the resistant line IIHR 352a (5.01). Arka Jeet a susceptible variety had the highest PDI of 66.78 per cent.

Among F_1 generations Arka Jeet X IIHR 190-1 recorded the minimum PDI of 4.37 followed by A. Jeet X IIHR 352a (7.66). In F_2 generation also Arka Jeet X IIHR 190-1 had a minimum PDI of 26.69 followed by F_2 generation of A. Jeet X IIHR 352a with the PDI off 30.17.

Among B_1 generations PDI ranged from 5.68 in A.Jeet X IIHR 190-1 to 21.98 in A.Jeet X IIHR 352a. B_2 generation of A.Jeet X IIHR 352a had a higher PDI (34.84) compared to PDI of A.Jeet X IIHR 190-1 (31.65).

In April of 1996 PDI for resistant parent ranged from 5.62 (IIHR 190-1) to 6.80 (IIHR 352a). Arka Jeet recorded maximum PDI in all the crosses.

Among the F_1 generations the range of variation was from 6.8 in A.Jeet X IIHR 352b to 8.38 in A.Jeet X IIHR 352c. In F_2 generations, the PDI ranged from

27.32 (cross A.Jeet X IIHR 352b and A.Jeet X IIHR 190-1) to 31.68 (cross A.Jeet X IIHR 352a).

Variation in PDI in the range of 7.78 (A.Jeet X 190-1) to 13.41 (A.Jeet X IIHR 352a) in the B1 generation and from 29.28 (A.Jeet X IIHR 190-1) to 42.62 (A.Jeet X IIHR 352a) in B_2 generation was observed.

4.1.2 Genetic parameters of Alternaria leaf blight

The estimates of mean, genotypic and phenotypic variance, coefficient of variations, heritability, genetic advance and genetic gains in the F_2 segregating generations of A. Jeet X IIHR 352a, A. Jeet X IIHR 190-1 (in two seasons), A. Jeet X IIHR 352b and A. Jeet X IIHR 352c for Alternaria leaf blight PDI were studied (Table 7).

During October 1995, F_2 progenies of the cross A. Jeet X IIHR 352a showed the maximum phenotypic variance (1157.44) and genotypic variance (1141.66) for Alternaria leaf blight PDI. However phenotypic coefficients of variation (137.36) and genotypic coefficient of variation (136.36) were the highest in the F_2 progeny of the cross A. Jeet X IIHR 190-1.

Heritability in broad sense was the maximum (98.54%) in the cross A. Jeet X IIHR 190-1 while heritability in narrow sense was the maximum in the cross A. Jeet X IIHR 352a (89.45).

Genetic advance was higher in the cross A. Jeet X IIHR 352a compare to the cross A. Jeet X IIHR 190-1. Genetic gain with broad sense heritability was the maximum (277.32%) in the cross A. Jeet X IIHR 190-1. Whereas with narrow sense heritability genetic gain was the maximum in the cross A. Jeet X IIHR 352a (226.85).

Table 7 Genetic parameters for Alternaria leaf blight (PDI) studied in F_2 of different crosses.

Crosses	Mean ± S.E	Phenotypic Variance	Genotypic Variance	P.C.V	G.C.V	h^2bs(%)	h^2ns(%)	G.A h^2bs	G.A h^2ns	G.g h^2ns	G.g h^2bs
October 1995											
A.Jeet x 352a	30.17 ± 1.56	1175.44	1141.06	123.13	122.25	98.5	89.45	69.03	62.68	249.83	226.85
A.Jeet x 190-1	26.69 ± 1.35	988.72	174.34	137.36	136.36	98.54	70.42	63.48	45.61	277.32	199.25
April 1996											
A.Jeet x 352a	31.68 ±1.42	869.63	843.64	101.69	100.16	97.01	79.91	58.93	47.97	203.31	165.48
A.Jeet x 352b	27.32 ± 1.53	842.42	820.42	103.43	102.04	97.32	94.38	58.06	56.11	206.66	200.66
A.Jeet x 352c	27.61 ± 1.35	826.44	798.5	114.85	112.89	96.61	90.74	56.85	53.29	227.12	212.93
A.Jeet x 190-1	27.32 ±1.25	755.34	731.32	105.5	103.81	96.8	84.25	54.35	47.55	208.62	182.56

During April 1996 F_2 progenies of the cross A. Jeet X IIHR 352a showed the maximum genotypic and phenotypic variance (869.63 and 843.64 respectively). The lowest genotypic and phenotypic variance (755.34 and 731.32) was recorded in the F_2 progenies of the cross A. Jeet X IIHR 190-1. Phenotypic coefficient of variation was the maximum in the cross A. Jeet X IIHR 352c and it was the lowest in the cross A. Jeet X IIHR 352a. The maximum GCV of 112.89 was recorded in the F_2 progenies of the cross A. Jeet X IIHR 352c and the minimum was in the cross A. Jeet X IIHR 352a (100.16).

Heritability in broad sense and narrow sense were the maximum (97.32 and 94.38% respectively) in the cross A. Jeet X IIHR 352b whereas heritability in broad sense was the lowest in the cross A. Jeet X IIHR 352c (96.61%). Narrow sense heritability was the minimum in the cross A. Jeet X IIHR 190-1 (84.25%).

Genetic advance with broad sense heritability was moderate in all the crosses. It was the highest in the cross A. Jeet X IIHR 352a (58.93) and the least in the cross A. Jeet X IIHR 190-1 (54.35).

Genetic advance with narrow sense heritability was also moderate in all the crosses. It was in the range of 47.55 (A. Jeet X IIHR 190-1) to 56.11 (A. Jeet X IIHR 352b).

All the crosses showed a very high genetic gain with broad sense and narrow sense heritability. The cross A. Jeet X IIHR 352c recorded the maximum genetic gain (227.12 and 212.93%) and it was the lowest in the cross A. Jeet X IIHR 190-1 (208.62 and 182.56%).

4.1.3 Assessment of six generations of different crosses to Alternaria leaf blight PDI

Six generations viz. P_1, P_2, F_1, F_2, B_1 and B_2 of the crosses A.Jeet X IIHR 190-1 were evaluated for the intensity of Alternaria leaf blight. Mean and variances

for per cent disease index (PDI) is presented for all the crosses for two seasons (October 1995 and April 1996) in Table 8.

4.1.3.1 Mean and variances for Alternaria leaf blight PDI in the six generations of the cross A.Jeet X IIHR 352a during October 1995

Resistant parent IIHR 352a recorded a mean disease index of 5.01 which was the lowest among all the progenies. Susceptible parent Arka Jeet recorded the PDI of 66.78 which was the highest among the six generations. Mean PDI in F_1 was 7.66 per cent and that of F_2 was 30.17. The back cross generation (B_2) observed a PDI of 34.84 while that of in B_1 it was 21.98. F_2 generation recorded the highest variance of 560.95 followed by 362.34 in B_2 generation. Lowest variance for per cent disease index was recorded in resistant parent 352a (6.57) followed by F_1 (18.68) and P_2 Arka Jeet (23.89).

4.1.3.2 Mean and variances for Alternaria leaf blight PDI in the six generations of the cross IIHR A.Jeet X 190-1 during October 1995

Highest mean per cent disease index was observed in the susceptible parent Arka Jeet (66.78) followed by B_2 generation (31.65). F_2 generation had recorded a disease index of 26.69%. The lowest per cent disease index was recorded in resistant parent IIHR 190-1 (2.22) followed by F_1 (4.37) and B_1 (5.68) generations. The maximum variance for per cent disease index was recorded in F_2 generation (432.07) followed by B_2 generation (404.43) and B_1 generation (111.50). Resistant parent IIHR 190-1 had the lowest variance of 4.52 followed by F_1 (14.72) generations.

4.1.3.3 Mean and variances for Alternaria leaf blight PDI in the six generations of the cross A.Jeet X IIHR 352a during April 1996.

Disease manifestation was the lowest in the resistant parent IIHR 352a (6.8) followed by F_1 (8.09) and B_1 (13.41) generations. Susceptible parent Arka Jeet

Table 8 Mean and Variances of six generations of different crosses for Alternaria leaf blight (PDI)

Crosses	P_1		P_2		F_1		F_2		B_1		B_2	
	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance
Oct.1995												
A.Jeet x 352a	5.01 ± 0.34	6.57	66.78 ± 0.78	23.89	7.66 ± 0.61	18.68	30.17 ± 1.56	560.95	21.98 ± 1.53	241.85	34.84 ±0.84	362.34
A.Jeet x 190-1	2.22 ± 0.30	4.52	66.78 ± 0.78	23.89	4.37 ± 0.54	14.72	26.69 ± 1.35	432.07	5.68 ± 0.33	111.50	31.65 ± 1.99	404.43
April 1996												
A.Jeet x 352a	6.8 ± 0.48	13.0	69.10 ± 1.01	51.17	8.09 ± 0.50	13.18	31.68 ± 1.42	410.65	13.41 ± 0.96	196.77	42.63 ± 1.33	277.03
A.Jeet x 352b	6.44 ± 0.41	9.16	68.75 ± 1.00	50.52	6.8 ± 0.39	7.99	27.32 ± 1.53	426.57	10.64 ± 0.72	171.87	27.59 ±1.68	283.46
A.Jeet x 352c	6.48 ± 0.46	11.34	68.20 ± 0.98	48.35	8.38 ± 0.68	24.14	27.61 ±1.35	415.06	10.77 ± 0.81	67.13	41.73 ± 1.37	188.00
A.Jeet x 190-1	5.62 ± 0.38	4.53	68.81±1.0	50.62	7.08 ± 0.57	16.90	27.32 ± 1.25	365.96	7.76 ± 0.41	18.68	39.28 ± 1.42	255.02

recorded maximum PDI of 69.10 per cent followed by B_2 (42.62) and F_2 (31.68) generations. Maximum variance for PDI was observed in F_2 generation (410.65) followed by B_2 generation (277.03). Resistant parent IIHR 352a had the lowest variance of 13.0 followed by F_1 generation (13.18).

4.1.3.4 Mean and variances for Alternaria leaf blight PDI in the six generations of the cross Arka Jeet X IIHR 352b during April 1996.

Arka Jeet recorded the maximum mean per cent disease index (68.75) followed by B_2 (37.89) generation. The minimum disease manifestation was observed in resistant parent (6.44) followed by F_1 (6.8) and B_1 generations (10.64). The maximum variance for per cent disease index was observed in F_2 generation (426.57) followed by B_2 generation (283.46). Variance for per cent disease index was lowest in F_1 generation (7.99) followed by resistant parent IIHR 352b (9.16) and P_2 (56.52).

4.1.3.5 Mean and variances for Alternaria leaf blight PDI in the six generations of the cross A. Jeet X IIHR 352c during April 1996.

The disease manifestation was the lowest in resistant parent IIHR 352c (6.44) followed by F_1 (6.8) and B_1 (10.64) generations. The highest mean per cent disease index was recorded in susceptible parent Arka Jeet (68.20) followed by B_2 (41.74) and F_2 (27.61) generations. The maximum variance for per cent disease index was observed in F_2 generation (415.06) and the minimum in resistant parent IIHR 352c (11.34)

4.1.3.6 Mean and variances for Alternaria leaf blight PDI in the six generations of the cross Arka Jeet X IIHR 190-1 during April 1996.

Mean per cent disease index was in the range of 5.62 in resistant parent IIHR 190-1 to 68.81 in susceptible parent Arka Jeet. F_1 generation recorded 7.08% mean

PDI followed by B_1 (7.76), F_2 (27.32) and B_2 (39.28) generations. The maximum variance for per cent disease index was observed in F_2 generation (365.76) followed by B_2 generation (255.02). Least variance was recorded in the resistant parent IIHR 190-1 (4.53) and F_1 generation (16.90).

4.1.4 Components of gene action through six generation mean analysis, for Alternaria leaf blight PDI

The results of Mather's scaling test, Joint scaling test, chi-square test and estimates of six genetic parameters viz m, [d], [h], [i], [j] and [l] for the observed mean of six generations of different crosses are presented in Table 9 and 10.

4.1.4.1 Components of gene action for Alternaria leaf blight PDI in the six generations of the cross A.Jeet X IIHR 352a during October 1995.

Significance of scaling test A and C indicated the inadequacy of additive-dominance model to explain the inheritance of Alternaria leaf blight resistance in IIHR 352a. In the same population the observations were subjected to joint scaling test. Highly significant estimates of m, [d] and [h] and very high significance of chi square test once again disproved the adequacy of additive-dominance model. Estimates of mean, additive, dominance and additive X dominance components were significant. Magnitude of dominance component was higher than that of additive [d] component. Type of epistasis was complimentary as indicated by the same sign of dominance [h] and dominance x dominance [l] parameters.

4.1.4.2 Six generations of the cross A.Jeet X IIHR 190-1 during October 1995.

Significance of scaling test A and C, of Mathers test and significant estimates of m, [d] and [h] of joint scaling test followed by highly significant chi square test indicated the inadequacy of simple additive-dominance model to study the inheritance of Alternaria leaf blight resistance in IIHR 190-1. It also suggested the presence of

Table 9 Scaling tests and estimation of gene effects for alternaria leaf blight (PDI) in different crosses during October 1995

	Crosses	
	A.Jeet x IIHR 352a	A.Jeet x IIHR 190-1
Mathers scaling test		
A	31.29 ± 3.14**	4.77 ± 0.91**
B	-4.74 ± 3.92	-7.84 ± 4.11
C	33.58 ± 6.45**	29.03 ± 5.58
Joint scaling test		
Mean	-43.17 ± 0.46**	-128.04 ± 0.57**
[d] additive	80.04 ± 0.46**	170.78 ± 0.55**
[h] dominance	57.76 ± 0.76**	125.75 ± 0.81**
χ^2 test	**	**
6 Factors		
[m] mean	42.93 ± 7.93**	66.61 ± 6.76**
[d] additive	-12.87 ± 2.43**	-32.0 ± 0.47**
[h] dominance	-35.26 ± 7.96**	-62.0 ± 16.29**
[i] additive x additive	-7.03 ± 7.92	-32.11 ± 6.74**
[j] additive x dominance	18.01 ± 2.47**	6.3 ± 2.07**
[l] dominance x dominance	-19.51 ± 11.66	35.19 ± 9.82
Type of epistasis	Complementary	Duplicate

Table 10 Scaling tests and estimation of gene effects for Alternaria leaf blight (PDI) of different crosses during April 1996

	Crosses			
	A.Jeet X IIHR 352a	A.Jeet X IIHR 352b	A.Jeet X IIHR 352c	A.Jeet X IIHR 190-1
Mathers scaling test				
A	11.92 ± 2.05**	8.03 ± 1.55**	6.68 ± 1.83**	2.85 ± 1.06**
B	8.05 ± 2.92**	0.22 ± 3.53	6.89 ± 2.99*	2.68 ± 3.10
C	34.65 ± 5.9**	20.48 ± 6.27**	19.02 ± 5.71**	20.67 ± 5.24**
Joint scaling test				
Mean	-5.33 ± 0.52**	-33.68 ± 0.53**	-8.10 ± 0.52**	-138.32 ± 0.57**
[d] additive	43.35 ± 0.53**	71.93 ± 0.53**	44.78 ± 0.52**	182.13 ± 0.57**
[h] dominance	17.61 ± 0.74**	41.84 ± 0.68**	21.58 ± 0.86**	148.19 ± 0.83**
χ^2 test	**	**	**	**
6 Factors				
[m] mean	52.62 ± 6.6**	49.82 ± 7.16**	42.78 ± 6.32**	52.36 ± 5.8**
[d] additive	-31.15+_0.56**	-31.15 ± 0.54**	-30.86 ± 0.54**	-31.59 ± 0.52**
[h] dominance	-44.53 ± 6.62**	-43.02 ± 7.17**	-34.40 ± 1.6**	-45.28 ± 5.8**
[i] additive X additive	-14.66 ± 6.58*	-12.22 ± 7.14	-5.4 ± 6.3	-15.14 ± 5.83**
[j] additive X dominance	1.93 ± 1.73	3.9 ± 1.91*	-0.15 ± 1.68	0.08 ± 1.58
[l] dominance X dominance	-5.31 ± 8.83	-3.96 ± 9.64	-8.14 ± 8.57	9.6 ± 7.96
Type of epistasis	Complementary	Complementary	Complementary	Duplicate

digenic non-allelic interaction of genes. All the 6 parameters of the gene action were significant. Dominance (-62) and dominance X dominance (35.19) were higher in magnitude when compared to additive (32), additive X additive (32.11) and additive X dominance (6.30) components. Different signs of [h] and [l] indicated the presence of duplicate epistasis.

4.1.4.3 Six generations of the cross A. Jeet X IIHR 352a during April 1996.

Significant deviation of all the scaling tests from zero indicated the inadequacy of additive dominance model to explain the inheritance of Alternaria leaf blight resistance in muskmelon breeding line IIHR 352a. This was further reinforced by the significant estimation of m, [d] and [h] components in joint scaling test and high significance of chi square test. The estimates of mean (m), additive [d], dominance [h] and additive X additive [i] components were significant whereas additive X dominance [i], and dominance X dominance [l] components were non significant. The magnitude of dominance [h] was more than additive [d] component. Complimentary epistasis was concluded by looking at the similar sign of [h] and [l] components.

4.1.4.4 Six generations of the cross A.Jeet X IIHR 352b during April 1996.

Scaling test A and C deviated significantly from zero indicating the inadequacy of additive-dominance model. Estimates of m, [d] and [h] of joint scaling test were highly significant followed by highly significant chi square test once again emphasised the inadequacy of additive - dominance model. Mean, additive, dominance and additive x dominance components were highly significant. Magnitude of dominance (43.02) was higher than that of additive (31.15) component. Similar signs of dominance and dominance x dominance components indicated the complementary type of epistasis.

4.1.4.5 Six generations of the cross A.Jeet X IIHR 352c during April 1996

Inadequacy of additive-dominance model to explain inheritance of Alternaria leaf blight resistance in muskmelon line IIHR 352c was evidenced by the significance of scaling test A, B and C. This was further supported by significant estimates of m, [d] and [h] components and significant chi square test, during joint scaling test. Mean (m), additive [d] and dominant [h] components were highly significant where as interaction components like additive x additive, additive X dominance and dominance X dominance were non significant. Magnitude of dominance component (34.40) was higher than the additive component (30.86). Similar signs of [h] and [l] indicated the presence of complementary epistasis.

4.1.4.6 Six generations of the cross A.Jeet X IIHR 190-1 during April 1996

Significance of scaling tests A and C and, significant estimates of m, [d] and [h] in joint scaling test and significant chi square test indicated the inadequacy of additive - dominance model to explain the inheritance of resistance to Alternaria leaf blight in muskmelon line IIHR 190-1. Estimates of mean, additive, dominance and additive X additive were highly significant while additive X dominance and dominance X dominance were non significant. Magnitude of dominance component (45.28) was higher than additive component (31.59). Signs of dominance and dominance X dominance components were of different type indicated the duplicate type of epistasis.

4.2 GENETICS OF DOWNY MILDEW IN MUSKMELON.

4.2.1 Analysis of variance.

The mean performance and analysis of variances of six generations in the two sets viz. A.Jeet X IIHR 352a and A.Jeet X IIHR 190-1 for per cent disease index

of downy mildew was studied for two seasons (October 1995 and April 1996). Other two crosses viz A.Jeet X IIHR 352b and A.Jeet X IIHR 352c were evaluated only in April 1996. The results of these studies are presented in Table 11 and 12.

4.2.1.1 Analysis of variance for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352a during October 1995.

The analysis of variance displayed significant difference among the six generations for per cent disease index (PDI) of downy mildew (Table 11).

Resistant parent IIHR 352a recorded a PDI of 10.86 which was significantly lower than all other generations. Susceptible parent Arka Jeet recorded significantly higher PDI (84.93) than all other generations. PDI of F_1 (25.62) and F_2 (25.23) were on par with each other. Back cross generation B_1 had a PDI of 20.32 per cent which was significantly lower than all other generations except P_1 generation. PDI of B_2 generation (45.61) was significantly higher than P_1, F_1, F_2 and B_1 generations but lower than P_2 generation.

4.2.1.2 Analysis of variance for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 190-1 during October 1995.

Resistant parent IIHR 190-1 had recorded the lowest PDI of 5.27 which was on par with B_2 generation (9.52). F_1 and F_2 generations recorded the intermediate PDI of 21.97 and 19.31 respectively. Susceptible parent Arka Jeet recorded a PDI of 84.98 which was significantly higher than all other generations. PDI of B2 generation (39.92) was significantly higher than P_1, F_1, F_2 and B_1 generations and less than Arka Jeet.

Table 11 Generation means and their analysis of variance for Downy mildew (PDI) in the six generarion of different crosses during October 1995

Generation	Crosses	
	A.Jeet x 352a	A.Jeet x 190-1
P_1	10.86[a]	5.27[a]
P_2	84.93[e]	84.98[d]
F_1	25.62[c]	21.97[b]
F_2	25.23[c]	19.31[b]
B_1	20.32[b]	9.52[a]
B_2	45.61[d]	39.92[c]
F test	**	**
C.D at 5%	4.34	5.22
S.Em	1.44	1.73

Table 12 Geneation means and their analysis of variance for downy mildew (PDI) in the six generation of different crosses during April 1996

Generation	Crosses			
	A.Jeet x 352a	A.Jeet x 352b	A.Jeet x 352c	A.Jeet x 190-1
P_1	8.11[a]	5.27[a]	4.65[a]	6.79[a]
P_2	76.23[e]	76.13[e]	76.13[e]	76.13[e]
F_1	15.00[b]	21.18[c]	18.13[b]	16.83[b]
F_2	29.22[c]	19.32[c]	30.71[c]	24.56[c]
B_1	16.83[b]	9.56[b]	15.81[b]	23.45[c]
B_2	51.14[d]	39.92[d]	46.16[d]	49.32[d]
F test	**	**	**	**
C.D at 5%	3.58	4.26	4.54	4.47
S.Em	1.19	1.42	1.51	1.49

4.2.1.3 Analysis of variance for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352a during April 1996.

Susceptible variety Arka Jeet recorded significantly higher PDI (76.23) for downy mildew. PDI of F_1 generation (15.00) and B_1 generation (16.83) were on par with each other. Per cent disease index of F_2 generation (29.22) was significantly higher than P_1, F_1 and B_1 generations but lower than P_2 and B_2 generations. The lowest disease index was recorded in resistant parent IIHR 352a (8.11) which diffired significantly from other generations.

4.2.1.4 Analysis of variance for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352b during April 1996.

The resistant parent IIHR 352a had the least pecentage of downy mildew infection as indicated by PDI 5.27 which was on par with that of B_1 generation (9.56). Mean PDI of F_1 (21.18) and F_2 (19.56) were on par with each other. Back cross generation B_2 had a PDI of 39.92 which was significantly higher than P_1, F_1, B_1 and F_2 generations. Highest disease manifestation was observed in P_2 i.e. susceptible parent Arka Jeet (76.13) which was significantly higher than all other generations.

4.2.1.5 Analysis of variance for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352c during April 1996.

The lowest disease index was recorded in the resistant parent IIHR 352c (4.65) which was significantly differing from all other generations. Mean PDI of F_1 (18.13) and B_1 (18.81) were on par with each other. F_2 (30.71) and B_2 (46.16) were significantly differing with each other. Susceptible parent Arka Jeet had the highest PDI of 76.13 which was significantly higher than all other generations.

4.2.1.6 Analysis of variance for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 190-1 during April 1996.

Significantly higher per cent disease index was recorded on susceptible parent Arka Jeet (76.10) where as significantly lower per cent disease index was recorded on resistant parent IIHR 190-1 (6.79). There was no significant differences between the PDI of F_2 and B_2 generations. B_2 generation had a significantly higher per cent disease index (49.38) than P_1, F_1, F_2 and B_1 generations but lower than P_2 generation.

During October 1995 six generations viz P_1, P_2, F_1, F_2, B_1 and B_2 of the cross A. Jeet X IIHR 190-1 had the lowest per cent disease index compared to the six generations of the cross A. Jeet X IIHR 352a.

Of the four resistant parents in April 1996, IIHR 352c had the lowest PDI (4.65) and was maximum in IIHR 352a (8.11). Susceptible parent Arka Jeet had the highest per cent disease index of 76.23.

Among the F_1 progenies, PDI ranged from 15.0 (cross A. Jeet X IIHR 352a) to 21.18 (cross A.Jeet X IIHR 352b). All the F_1 generations were in the resistant group.

The range of PDI in F_2 generation was from 19.32 (cross A.Jeet X IIHR 352b) to 30.71 (cross A.Jeet X IIHR 352c).

Progenies of B_1 generations in all the crosses recorded a low PDI for downy mildew. It was the least in the B_1 generation of the cross A.Jeet X IIHR 352b (9.56) and highest in the B_1 generation of the cross A. Jeet X IIHR 190-1 (23.45). B_2 generations of all this crosses had a moderately higher PDI for downy mildew. It was in the range of 39.92 (cross A.Jeet X IIHR 352b) to 51.14 (cross A. Jeet X IIHR 352a).

4.2.2 Genetic parameters of downy mildew.

The estimates of mean, genotypic and phenotypic variance, coefficient of variations, heritability, genetic advance and genetic gains in the F_2 segregating generations of A. Jeet X IIHR 352a, A. Jeet X IIHR 190-1 (in two seasons), A. Jeet X IIHR 352b and A. Jeet X IIHR 352c for downy mildew PDI were studied (Table 13).

During October 1995, the cross A. Jeet X IIHR 352a recorded the maximum genotypic variance (1399.4) and phenotypic variance (1440.61). But the GCV and PCV were maximum (106.96 and 108.93) in the cross A. Jeet X IIHR 190-1.

Heritability in broad sense was maximum (97.41%) in the cross A. Jeet X IIHR 352a whereas heritability in narrow sense was the maximum in the cross A. Jeet X IIHR 190-1 (46.8%). Genetic advance with broad sense heritability was the maximum in the cross A. Jeet X IIHR 352a (75.84) and with narrow sense heritability was the maximum in the cross A. Jeet X IIHR 190-1 (44.9).

Genetic gain with broad sense heritability (216.34) and with narrow sense heritability (145.4%) were the maximum in the cross A. Jeet X IIHR 190-1.

During April 1996 F_2 progenies of the cross A. Jeet X IIHR 352b recorded the lowest mean PDI followed by F2 progenies of the cross A. Jeet X IIHR 190-1. It was maximum in the cross A. Jeet X IIHR 352c (30.71%)

Phenotypic variance was the highest (1675.79) in the F_2 progenies of the cross A. Jeet X IIHR 352c and the lowest in the cross A. Jeet X IIHR 352b. Similar trend was observed for the genotypic variance. F_2 progenies of the cross A. Jeet X IIHR 352c (1656.36) had the highest genotypic variance followed by the cross A. Jeet X IIHR 190-1 (1151.56). The lowest genotypic variance was observed in the F_2 progenies of the cross A. Jeet X IIHR 352b (713.72).

Table 13 Genetic parameters for Downy mildew (PDI) studied in F_2 of different crosses.

Crosses	Mean ± S.E	Phenotypic Variance	Genotypic Variance	P.C.V	G.C.V	h^2bs(%)	h^2ns(%)	G.A		G.g	
								h^2bs	h^2ns	h^2ns	h^2bs
Oct.1995											
A.Jeet x 352a	25.23 ± 1.36	1440.61	1399.4	105.40	103.88	97.41	42.24	75.84	32.84	210.06	91.19
A.Jeet x 190-1	19.31 ± 1.12	1134.62	1093.86	108.93	106.96	96.40	46.80	66.89	44.90	216.34	145.24
April 1996											
A.Jeet x 352a	29.22 ±1.27	880.47	866.62	90.66	89.63	98.43	86.92	59.90	53.13	183.02	162.33
A.Jeet x 352b	19.32 ± 1.10	745.86	713.72	90.85	88.87	95.69	68.85	53.44	38.85	177.79	127.26
A.Jeet x 352c	30.17 ± 1.51	1675.79	1656.36	148.05	147.19	98.84	49.18	83.41	41.47	301.63	149.99
A.Jeet x 190-1	24.56 ±1.42	1169.56	1151.56	123.58	122.78	98.40	68.43	69.04	47.90	249.69	173.25

Phenotypic and genotypic coefficient of variations were the maximum in the cross A. Jeet X IIHR 352c (148.5 and 147.19 respectively). Least PCV and GCV were recorded in the cross A. Jeet X IIHR 352b (90.85 and 88.87 respectively). Phenotypic coefficient of variation was generally higher than the genotypic coefficient of variation.

Heritability estimates in broad sense was very high in all the crosses. It was the highest in the cross A. Jeet X IIHR 352c (98.84%) and the lowest in the cross A. Jeet X IIHR 352b (95.69%).

Narrow sense heritability was also moderate to high in all the crosses. The cross A. Jeet X IIHR 352a recorded the maximum heritability of 86.92 per cent followed by 68.55 per cent in the cross A. Jeet X IIHR 352b. The lowest heritability was recorded in the cross A. Jeet X IIHR 352c (49.18%).

Genetic advance with broad sense heritability was moderate to high in all the crosses. The highest genetic advance was recorded in the cross A. Jeet X IIHR 352c (83.4) and the lowest was recorded in the cross A. Jeet X IIHR 352b (53.44). Genetic advance with narrow sense heritability was maximum in the cross A. Jeet X IIHR 352a (53.18) and was the lowest in the cross A. Jeet X IIHR 352b (38.35).

Genetic gain over the mean was very high for all the crosses when broad sense heritability was considered. The highest genetic gain of 301.63 per cent was observed in the cross A. Jeet X IIHR 352c and the lowest was in the cross A. Jeet X IIHR 352b (177.79%). When narrow sense heritability was considered genetic gains were comparatively lower in all the crosses. The maximum genetic gain of 162.33 per cent was observed in the cross A. Jeet X IIHR 352a in the least was 127.26 per cent in the cross A. Jeet X IIHR 352b.

4.2.3 Evaluation of different crosses for the reaction to downy mildew PDI

Six generations viz P_1, P_2, F_1, F_2, B1 and B_2 of the crosses A. Jeet X IIHR 352a, A.Jeet X IIHR 352b, A.Jeet X IIHR 352c and A. Jeet X IIHR 190-1 were

evaluated for the downy mildew reaction. Mean and variance for per cent disease index (PDI) are presented in the Table 14.

4.2.3.1 Mean and variances for downy mildew PDI in the six genera tions of the cross A. Jeet X IIHR 352a during October 1995.

Resistant parent IIHR 352a recorded the lowest mean PDI of 10.86 followed by B_1 (20.32), F_2 (25.32) and F_1 (25.62) generations. The highest PDI was recorded in the susceptible parent Arka Jeet (84.93) followed by B_2 generation (45.61). The maximum variance for downy mildew per cent disease index was noticed in the F_2 generation (495.77) followed by B_2 generation (468.97). The minimum variance was observed in resistant parent IIHR 352a (25.17), susceptible parent Arka Jeet (45.02) and their F_1 generation (53.45).

4.2.3.2 Mean and variances for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 190-1 during october 1995.

Susceptible parent Arka Jeet recorded the maximum mean per cent disease index of 84.98 followed by 39.92 in B_2 generation and 21.97 in F_1 generation. Mean PDI was the lowest in the resistant parent IIHR 190-1 (5.27) followed by B_1 generation (9.52) and F_2 (19.31) generations. F_2 generation exhibited maximum variance for PDI (324.75) followed by B_2 (303.70). Resistant parent IIHR 190-1 recorded the lowest variance (18.09) followed by the susceptible parent Arka Jeet (43.76) and F_1 generation (60.42).

4.2.3.3 Mean and variances for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352a during April 1996.

Mean per cent disease index was the lowest in the resistant parent IIHR 352a (8.11) followed by F_1 (15.0) and B_1 (16.83) generations. The maximum PDI for downy mildew was recorded in the susceptible parent Arka Jeet (76.13) followed by B_2 (51.41) and F_2 (29.22) generations. Variance for PDI was the maximum in

Table 14 Mean and Variances of six generations of different crosses for Downy mildew (PDI)

Crosses	P_1		P_2		F_1		F_2		B_1		B_2	
	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance
Oct.1995												
A.Jeet x 352a	10.86 ± 0.70	25.17	84.93 ± 0.95	45.02	25.62 ± 1.01	53.45	25.23 ± 1.36	495.77	20.32 ± 1.59	313.15	45.61 ± 2.16	468.97
A.Jeet x 190-1	5.27 ±0.60	18.09	84.98 ±0.93	43.76	21.97 ±1.06	60.42	19.31 ±1.12	324.75	9.52 ± 1.04	116.04	39.92 ± 1.74	303.70
April 1996												
A.Jeet x 352a	8.11 ± 0.54	15.49	76.23 ± 0.56	16.14	15.0 ± 0.43	9.85	29.22 ± 1.27	421.73	16.83 ± 1.35	184.91	51.14 ± 1.66	276.10
A.Jeet x 352b	5.27 ± 0.6	18.09	76.13 ± 0.56	16.14	21.81 ± 1.11	62.19	19.32 ± 1.10	321.12	9.56 ± 1.05	117.44	39.92 ± 1.74	303.70
A.Jeet x 352c	4.65 ± 0.47	11.28	76.13 ± 0.56	16.14	18.13 ± 0.77	30.85	30.71 ± 1.51	574.90	15.81 ± 0.84	75.30	46.14 ± 1.47	216.82
A.Jeet x 190-1	6.79 ± 0.67	23.04	76.10 ± 0.56	16.31	16.38 ± 0.54	14.65	24.56 ± 1.42	506.21	23.45 ± 1.65	272.78	49.38 ± 1.54	337.64

the F_2 generation (421.73) followed by B_2 generation (276.10) and was the minimum in F_1 generation (9.85) followed by resistant parent IIHR 352a (15.49) and susceptible parent Arka Jeet (16.21).

4.2.3.4 Mean and variances for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352b during April 1996.

Susceptible parent Arka Jeet had recorded the maximum mean PDI of 76.13 followed by 39.92 per cent in B_2 generation. The lowest mean disease index was noticed in the resistant parent IIHR 352b (5.27) followed by B_1 generation (9.56). F_2 and F_1 progenies had recorded a mean per cent disease index of 19.32 and 21.81 respectively. As for the variance was concerned, F_2 generation had shown the maximum variance (321.12) for downy mildew PDI followed by B_2 generation (303.70). Lowest variance was observed in the susceptible parent Arka Jeet (16.14) and resistant parent IIHR 352b (18.09).

4.2.3.5 Mean and variances for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352c during April 1996.

In this cross lowest mean per cent disease index was observed in resistant parent IIHR 352c (4.65) followed by B_1 generation (15.81). The highest mean PDI was recorded in the susceptible parent Arka Jeet (76.13) followed by B_2 generation (46.16). F_1 and F_2 generations recorded a mean PDI of 18.13 and 30.71 respectively. Variance for downy mildew PDI was the maximum in the F_2 generation (574.903) followed by B2 generation (216.82). Variance in F_1 generation (30.85) and B_1 generation (75.30) were comparatively low. The lowest variance was observed in resistant parent IIHR 352c (11.28) followed by susceptible parent Arka Jeet (16.14).

4.2.3.6 Mean and variances for downy mildew PDI in the six generations of the cross A. Jeet X 190-1 during April 1996.

Mean per cent disease index was the minimum in the resistant parent IIHR 190-1 (6.79) followed by F_1 generation (16.38). Moderate disease manifestation on the F_2 and B_1 generations was evident by the PDI of 24.56 and 23.45. The highest per cent disease index was recorded in the susceptible parent Arka Jeet (76.10) followed by B_2 generation (49.38). Similar to other crosses, variance for downy mildew (PDI) was maximum in F2 generation (506.21) followed by B_2 generation (339.64). Minimum variance was recorded in the F_1 generation (14.65) followed by susceptible parent Arka Jeet (16.31).

4.2.4 Components of gene action through six generation mean analysis for downy mildew PDI

Mathers scaling test A, B and C, joint scaling test, chi square test and six genetic parameters viz mean (m), additive [d], dominance [h], additive X additive [i], additive X dominance [j] and dominance X dominance [l] were estimated from the six generations viz P_1, P_2, F_1, F_2, B_1 and B_2 from the crosses A. Jeet X IIHR 352a, A.Jeet X IIHR 352b A.Jeet X IIHR 352c and A. Jeet X IIHR 190-1 and are presented in Table 15 and 16.

4.2.4.1 Components of gene action for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352a during October 1995.

Significance of scaling tests B and C indicated the inadequacy of additive - dominance model for explaining the inheritance of downy mildew resistance in the line IIHR 352a. This was further reinforced by the significance of m, [d] and [h] components of joint scaling test and highly significant chi square test. Mean, additive, additive x additive and additive X dominance components were highly significant. Estimates of dominance and dominance X dominance components were

Table 15 Scaling tests and estimation of gene effests for Downy mildew (PDI) in different crosses during October 1995

	Crosses	
	A.Jeet x IIHR 352a	A.Jeet x IIHR 190-1
Mothers Scaling test		
A	4.16 ± 3.42	-8.19 ± 2.43**
B	-19.33 ± 4.54**	-27.10 ± 3.76**
C	-46.10 ± 5.95**	-56.0 ± 5.09**
Joint Scaling test		
Mean	33.28 ± 0.57**	17.77 ± 0.54**
[d] additive	12.68 ± 0.58**	24.09 ± 0.54**
[h] dominance	-8.99 ± 1.13**	0.49 ± 1.11
χ^2 test	**	**
6 Factors		
m mean	16.96 ± 7.96**	23.49 ± 6.08*8
[d] additive	-37.32 ± 0.59**	-39.86 ± 0.56**
[h] dominance	8.66 ± 7.76	-1.52 ± 6.17
[i] additive x additive	30.93 ± 7.76**	21.63 ± 6.06**
[j] additive x dominance	11.75 ± 2.75**	9.45 ± 2.11**
[l] dominance x dominance	15.76 ±12.29	13.66 ± 9.60
Type of epistasis	Complementary	Duplicate

Table 16 Scaling tests and estimation of gene effects for Downy mildew (PDI) of different crosses during April 1996

	Crosses			
	A.Jeet X IIHR 352a	A.Jeet X IIHR 352b	A.Jeet X IIHR 352c	A.Jeet X IIHR 190-1
Mather's Scaling test				
A	10.54 ± 2.81**	-7.95 ± 2.46**	8.81 ± 1.91*	23.73 ± 3.41**
B	11.04 ± 3.40**	-26.94 ± 3.78**	-1.93 ± 3.09	6.29 ± 3.77
C	2.54 ± 5.24	-56.58 ± 5.08**	5.82 ± 6.30	-17.42 ± 5.86**
Joint Scaling test				
mean	40.95 ± 0.38**	17.83 ± 0.53**	32.93 ± 0.36**	46.32 ± 0.43**
[d] Additive	-0.17 ± 0.39	24.10 ± 0.54**	5.09 ± 0.36**	-6.21 ± 0.43**
[h] Dominance	-25.67 ± 0.58**	0.26 ± 1.13	-15.71 ± 0.80**	-30.11 ± 0.7**
χ^2 test	**	**	**	**
6 Factors				
m mean	23.17 ± 6.68**	23.44 ± 6.04**	39.31 ± 6.96**	24.56 ± 1.42**
[d] additive	-34.06 ± 0.39**	-39.85 ± 0.56**	-35.74 ± 0.37**	-34.65 ± 0.44**
[h] dominance	-8.13 ± 6.69	30.28 ± 15.22**	-21.17 ± 7.10**	22.37 ± 2.47**
[i] additive X additive	19.04 ± 6.67**	21.68 ± 6.01**	1.08 ± 6.95	47.44 ± 7.54**
[j] additive X dominance	-0.24 ± 2.18	9.49 ± 2.11**	5.39 ± 1.72**	8.72 ± 2.51?**
[l] dominance X dominance	-40.63 ± 10.06**	13.21 ± 9.6	-7.99 ± 9.26	-77.46 ± 11.50**
Type of epistasis	Complementary	complementary	complementary	Duplicate

nonsignificant. Magnitude of additive component (37.32) was higher than the dominance component (8.66). Similar signs of [h] and [l] components indicated the presence of complementary type of epistasis.

4.2.4.2 Components gene action for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 190-1 during October 1995.

Inadequacy of additive - dominance model was proved by the significance of scaling test A, B and C followed by the significant estimates of m, and [d] and highly significant chi square test. Estimates of mean, additive, additive X additive, additive X dominance components were highly significant. Dominance and dominance X dominance components were non significant. Magnitude of additive estimate was higher than that of dominance. Contrasting signs of [h] and [l] indicated the presence of duplicate epistasis.

4.2.4.3 Components of gene action for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352a during April 1996.

Significant deviation of scaling test A and B revealed the inadequacy of additive - dominance model to explain the inheritance of resistance to downy mildew in resistant musk melon line IIHR 352a. This was further supported by the significant estimates of m and [h] in joint scaling test and highly significant chi square test (Table 16).

The estimated m, [d], [i] and [l] were significantly higher than other estimates. Estimates of dominance and dominance, components were non significant. Magnitude of additive component was higher (34.06) than the dominance component (8.13). Complementary epistasis was evident by similar signs of [h] and [l] components.

4.2.4.4 Components of gene action for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352b during April 1996.

Scaling test A, B and C were highly significant indicated the inadequacy of additive - dominance model to explain the inheritance of resistance to downy mildew in the resistant muskmelon breeding line IIHR 352b. This hypothesis was further supported by the significant estimates of m and [d] components and highly significant estimation of chi square test during joint scaling test. Among six genetic estimates, the mean (m), additive [d], dominance [h], additive X additive [i], additive X dominance [l] were significant. Estimation of dominance X dominance [l] was non significant. Magnitude of additive [d] component (39.85) was higher than dominance component (30.28). Similar signs of [h] and [l] indicated the presence of complementary epistasis. (Table 16)

4.2.4.5 Components of gene action for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 352c during April 1996.

Significant deviation of scaling test A from zero indicated the inadequacy of additive - dominance model to explain the inheritance of resistance to downy mildew in resistant breeding line IIHR 352c. Further reinforcement of this hypothesis was done by significant estimates of m, [d] and [h] components and highly significant chi square test in joint scaling test. Estimates of mean, additive, dominance and additive X dominance were significant whereas additive X additive and dominance X dominance were non-significant. Magnitude of additive component (35.74) was higher than that of dominance component (21.17). Similar signs of dominance and dominance X dominance component indicated the complementary type of epistasis.

4.2.4.6 Components of gene action for downy mildew PDI in the six generations of the cross A.Jeet X IIHR 190-1 during April 1996.

Significance of scaling test A and C, highly significant estimates of m, [d] and [h] in joint scaling test and highly significant chi square test indicated the inadequacy of additive - dominance model to explain the inheritance of downy mildew resistance in the resistant muskmelon breeding line IIHR 190-1. Estimates of m, [d], [h], [i], [j] and [l] were highly significant. Magnitude of additive estimate (34.65) was higher than the dominance estimate. Duplicate type of epistasis was evident by the contrasting signs of dominance and dominance X dominance components (Table 16).

4.3 GENETICS OF POWDERY MILDEW RESISTANCE IN MUSKMELON.

4.3.1 Analysis of variance of six generations for powdery mildew PDI

Mean infection of powdery mildew in six generations viz P_1, P_2, F_1, F_2, B_1 and B_2 were subjected to analysis of variance. Results of analysis of variance for four crosses viz A. Jeet X IIHR 352a, A.Jeet X IIHR 352b, A.Jeet X IIHR 352c and A. Jeet X IIHR 190-1 for per cent disease index (PDI) of powdery mildew are presented in the Table 17.

4.3.1.1 Analysis of variance for powdery mildew PDI in the six generations of the cross A.Jeet X IIHR 352a.

Powdery mildew PDI on resistant parent IIHR 352a was very low (0.05) which was on par with F_1 (2.34) and B_1 (2.04) generations. Susceptible parent Arka Jeet recorded significantly higher PDI (75.49) than all other generations. Per cent disease index of F_2 (13.71) and B_2 (19.54) generations were on par with each other.

Table 17 Geneation means and their analysis of variance for Powdery mildew (PDI) in the six generation of different crosses

	Crosses			
Generation	A.Jeet x 352a	A.Jeet x 352b	A.Jeet x 352c	A.Jeet x 190-1
P_1	0.05[a]	0.04[a]	0.07[a]	0.24[a]
P_2	75.49[d]	75.28[d]	75.49[d]	75.42[d]
F_1	2.34[a]	0.83[a]	1.23[a]	0.80[a]
F_2	13.71[b]	14.96[b]	12.78[b]	10.87[b]
B_1	2.04[a]	3.05[a]	1.98[a]	1.97[a]
B_2	19.54[c]	23.22[c]	21.01[c]	29.80[c]
F test	**	**	**	**
C.D at 5%	5.58	3.24	3.82	4.23
S.Em	1.85	1.08	1.27	1.41

4.3.1.2 Analysis of variance for powdery mildew PDI in the six generations of the cross A.Jeet X IIHR 352b.

Significantly higher PDI for powdery mildew was observed in susceptible parent Arka Jeet (75.28). The lowest PDI was recorded in resistant parent IIHR 352b (0.04) which was on par with F_1 (0.83) and B_1 (3.05) generations. PDI estimates of F_2 (14.96) and B_2 (23.22) were significantly differing each other.

4.3.1.3 Analysis variance for powdery mildew PDI in the six generations of the cross A.Jeet X IIHR 352c.

In this cross also resistant parent IIHR 352c recorded the least incidence of powdery mildew (0.07) which was on par with the F_1 (1.23) and B_1 (1.98) generations. F_2 generation had recorded a PDI of 12.78 which was significantly higher than P_1, F_1 and B_1 generations and significantly lower than P_2 and B_1 generations. Susceptible parent Arka Jeet recorded the maximum PDI (75.49) which was significantly higher than all other generations.

4.3.1.4 Analysis of variance for powdery mildew PDI in the six generations of the cross Arka Jeet X IIHR 190-1.

Resistant parent 190-1 recorded the lowest PDI for powdery mildew (0.24) but it was on par with F_1 (0.80) and B_1 (1.97) generations. Mean manifestation of powdery mildew in F_2 generation was 10.87 which was significantly higher than P_1, F_1 and B_1 generations but less than P_2 generation. Susceptible parent Arka Jeet had the highest disease index of 75.42 which was significantly higher than all other generations.

4.3.2 Genetic parameters of powdery mildew resistance.

The estimates of mean, genotypic and phenotypic variance, coefficients of variances, heritability (broad sense and narrow sense) genetic advance and genetic gain over the mean of the population in the F_2 segregating generations of A. Jeet X IIHR 352a, A.Jeet X IIHR 352b, A.Jeet X IIHR 352c and A. Jeet X IIHR 190-1 for powdery mildew PDI are presented in the Table 18.

F_2 generations of all the crosses had a low mean per cent disease index. It was lowest in the F_2 progeny of the cross A. Jeet X 190-1 (10.87%) and highest in A.Jeet X IIHR 352b (14.96%). Segregating progenies of F_2 generations of the cross A. Jeet X IIHR 352a had a mean PDI of 13.71 per cent and that of 352c X A. Jeet was 12.78 per cent.

Phenotypic variance was the maximum in the cross A. Jeet X IIHR 190-1 (947.27) followed by A. Jeet X IIHR 352a (676.69). Phenotypic variance was the minimum in the cross A. Jeet X IIHR 352b. Genotypic variance for powdery mildew PDI was the maximum in the cross A. Jeet X IIHR 190-1 followed by the cross A. Jeet X IIHR 352a. The minimum genotypic variance was recorded in the cross A. Jeet X IIHR 352b (602.1).

Phenotypic coefficient of variation was higher than the genotypic coefficient of variation in all the crosses. The highest PCV was recorded in the cross A. Jeet X IIHR 190-1 (155.99) followed by the cross A. Jeet X IIHR 352a (137.92). The minimum PCV was recorded in the cross A. Jeet X IIHR 352c (125.95). Same trend was observed for genotypic coefficient of variation.

Heritability in broad sense and narrow sense were high for all the crosses. It was the maximum in the cross A. Jeet X IIHR 190-1 (99.70 and 86.56% respectively) and least was recorded in the cross A. Jeet X IIHR 352b (99.2 and 71.54%).

Table 18 Genetic parameters for powdery mildew (PDI) studied in F_2 of different crosses.

Crosses	Mean ± S.E	Phenotypic Variance	Genotypic Variance	P.C.V	G.C.V	h^2bs(%)	h^2ns(%)	G.A		G.g	
								h^2bs	h^2ns	h^2ns	h^2bs
A.Jeet x 352a	13.71 ± 1.0	676.69	672.06	137.92	136.47	99.31	62.12	53.05	33.22	281.29	176.16
A.Jeet x 352b	14.96 ± 1.02	606.94	602.10	125.95	124.44	99.20	61.52	50.24	30.95	256.85	158.27
A.Jeet x 352c	12.78 ± 1.17	641.69	636.31	135.02	134.52	99.22	71.54	51.46	36.53	274.30	194.72
A.Jeet x 190-1	10.87 ± 1.22	947.27	944.46	155.99	154.76	99.70	86.56	62.76	54.52	318.07	276.36

Genetic advance was moderate to high when broad sense heritability was considered and moderate when narrow sense heritability was considered. The highest genetic advance was recorded in the cross A. Jeet X IIHR 190-1 (62.76 and 54.52) and the least was in the cross A. Jeet X IIHR 352b (51.46 and 36.53).

Genetic gain over mean was very high for all the crosses. When broad sense heritability was considered it was the highest in the cross A. Jeet X IIHR 190-1 (318.09%) and the least in the cross A. Jeet X IIHR 352b (256.85%). Similar trend was observed for genetic gain when narrow sense heritability was considered.

4.3.3 Evaluation of six generations of different crosses for their reaction to powdery mildew PDI

Six generations viz P_1, P_2, F_1, F_2, B_1 and B_2 of the crosses A. Jeet X IIHR 352a, A.Jeet X IIHR 352b, A.Jeet X IIHR 352c and A. Jeet X IIHR 190-1 were evaluated for the PDI of powdery mildew. Mean and variance for plant disease index for all the crosses are presented in the Table 19.

4.3.3.1 Mean and variances for powdery mildew PDI in the six generations of the cross Arka Jeet X IIHR 352a.

Mean per cent disease index (PDI) was very low for all the generations except for the susceptible parent Arka Jeet. Resistant parent IIHR 352a recorded a very low PDI of 0.05 followed by B_1 (2.04), F_1 (2.34) and F_2 (13.71) generations. The maximum disease manifestation was recorded in the susceptible parent A. Jeet (75.49) followed by B_2 (19.54) generation. The maximum variance for powdery mildew per cent disease index was recorded in B_2 generation (326.63) followed by F_2 generation (250.46). The lowest variance was recorded in P_1 (0.04), F_1 (3.50) and P_2 (10.36) generations.

Table 19 Mean and Variances of six generations of different crosses for Powdery mildew (PDI)

Crosses	P_1		P_2		F_1		F_2		B_1		B_2	
	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance	Mean ± S.E	Variance
A.Jeet x 352a	0.05 ± 0.03	0.04	75.49 ± 0.45	10.36	2.34 ± 0.26	3.50	13.71 ± 1.00	250.46	2.04 ± 0.39	18.66	19.54 ± 1.63	326.63
A.Jeet x 352b	0.04 ± 0.02	0.03	75.28 ± 0.47	11.29	0.83 ± 0.15	1.17	14.96 ± 1.02	299.44	3.05 ± 0.33	11.47	23.22 ± 1.54	247.35
A.Jeet x 352c	0.07 ± 0.05	0.16	74.65 ± 0.51	13.50	1.23 ± 0.17	0.99	12.78 ± 1.17	354.08	1.98 ± 0.19	3.83	21.01 ± 2.11	451.51
A.Jeet x 190-1	0.26 ± 0.04	0.12	75.42 ± 0.38	7.59	0.80 ± 0.12	0.72	10.87 ± 1.22	421.24	1.97 ± 0.39	15.86	29.80 ± 2.93	461.99

4.3.3.2 Mean and variances for powdery mildew PDI in the six generations of the cross A.Jeet X IIHR 352b.

The PDI ranged from 0.04 to 75.28. The highest manifestation of disease severity was observed in Arka Jeet (75.28) followed by B_2 generation (23.22) and the lowest in IIHR 352a (0.04) followed by F_1 (0.83) and B_1 (3.05) generations. Estimates of variance was found the maximum in B_2 generation followed by F_2 generations.

4.3.3.3 Mean and variances for powdery mildew PDI in the six generations of the cross A.Jeet X IIHR 352c.

The maximum mean PDI was recorded in Arka Jeet (74.65) followed by B_2 (21.01) and F_2 generations (12.78). The minimum PDI was observed in IIHR 352c (0.07) followed by F_1 (1.23) and B_1 generations (1.98). The maximum variance was observed in B_2 generation followed by F_2 generation. Variance for PDI was least in P_1, F_1 and B_1 generations.

4.3.3.4 Mean and variance for powdery mildew PDI in the six generations of the cross A.Jeet X IIHR 190-1.

Powdery mildew per cent disease index was in the range of 0.28 to 75.42. The maximum PDI was recorded in Arka Jeet (75.42) followed by B_2 generation (29.80) and the minimum in IIHR 190-1 (0.26), F_1 (0.80) and B_1 generations (1.97). The maximum variance was observed in B_2 generation followed by F_2 generation and least was in P_1, F_1 and P_2 generations.

4.3.4 Components of gene action through six generation mean analysis for powdery mildew PDI

Mather's scaling tests viz A, B, and C joint scaling test and chi square test, and six genetic parameters viz mean (m), additive [d], dominance [h], additive X

additive [i], additive X dominance [j] and dominance X dominance [l] were estimated from the six generations viz P_1, P_2, F_1, F_2, B_1 and B_2 of the crosses A. Jeet X IIHR 352a, A. Jeet X IIHR 352b, A. Jeet X IIHR 352c and A. Jeet X IIHR 190-1, and are presented in Table 20.

4.3.4.1 Components of gene action for powdery mildew PDI in tthe six generations of the cross A. Jeet X IIHR 352a.

Significant deviation of scaling test A, B and C from zero indicated the inadequacy of additive-dominance model to explain the inheritance of resistance to powdery mildew in muskmelon breeding line IIHR 352a. Joint scaling test results i.e. significant estimates of m, [d] and [h] and highly significant chi-square test supported the inadequacy of additive dominance model. Genetic estimates, mean, additive, dominance, additive X additive, additive X dominance and dominance were significant. Magnitude of dominance was higher than that of additive component. Contrasting signs of [h] and [l] indicated the presence of duplicate epistasis.

4.3.4.2 Components of gene action for powdery mildew PDI in the six generations of the cross A. Jeet X IIHR 352b.

The scaling test A, B and C were significantly deviating from zero indicated the presence of nonallelic interaction. Significant estimates of m, [d] and [h] and highly significant chi square test stated the inadequacy of additive dominance model. The estimates of mean (m), additive [d], dominance [h] additive X dominance [j] and dominance X dominance [l] were highly significant. Magnitude of estimates of dominance was considerably larger than the estimates of additive components. Opposite signs of [h] and [l] indicated the presence of duplicate epistasis.

4.3.4.3 Components of gene action for powdery mildew PDI in the six generations of the cross A. Jeet X IIHR 352c.

Inadequacy of additive - dominance model to explain the inheritance of powdery mildew resistance in muskmelon breeding line IIHR 352c was evidenced

Table 20 Scaling tests and estimation of gene effects for powdery mildew (PDI) of different crosses

	Crosses			
	A.Jeet X IIHR 352a	A.Jeet X IIHR 352b	A.Jeet X IIHR 352c	A.Jeet X IIHR 190-1
Mather's Scaling test				
A	1.67 ± 0.83*	5.22 ± 0.69**	2.66 ± 0.43**	2.87 ± 0.80**
B	-38.74 ± 3.31**	-29.66 ± 3.14**	-33.86 ± 4.26**	-16.62 ± 5.89**
C	-25.39 ± 4.06**	-17.15 ± 4.14**	-26.07 ± 4.76**	-33.81 ± 4.91**
Joint Scaling test				
m mean	-4303.53 ± 0.23**	-6460.33 ± 0.25**	-2563.81 ± 0.34**	-1287.00 ± 0.20**
[d] additive	4345.11 ± 0.23**	6503.87 ± 0.25**	2602.19 ± 0.34**	1327.29 ± 0.20**
[h] dominance	4395.88 ± 0.35**	6502.43 ± 0.29**	2541.23 ± 0.40**	1290.43 ± 23**
χ^2 test	**	**	**	**
6 Factor				
m mean	49.45 ± 5.23**	44.95 ± 5.19**	42.49 ± 6.35**	17.77 ± 7.68**
[d] additive	-37.72 ± 0.22**	-37.62 ± 0.24**	-37.29 ± 0.26**	-37.58 ± 0.19**
[h] dominance	-58.07 ± 12.90**	-38.16 ± 12.57**	-40.21 ± 15.87*	27.21 ± 20.29
[i] additive X additive	-11.68 ± 5.23*	-7.29 ± 5.18*	-5.12 ± 6.34	20.07 ± 7.68**
[j] additive X dominance	20.21 ± 1.70**	17.44 ± 1.60**	18.26 ± 2.12**	9.74 ± 2.97**
[l] dominance X dominance	48.74 ± 7.86**	31.73 ± 7.57**	36.32 ± 9.73**	-6.33 ± 12.82
Type of Epistasis	Duplicate	Duplicate	Duplicate	Duplicate

by the significance of scaling test A, B and C followed by the significant estimates of m, [d] and [h] in the joint scaling test and highly significant chi square test. Mean (m), additive [d] dominance [h], additive X dominance [j], and dominance X dominance [l] were highly significant. Magnitude of estimates of dominance component was larger than that of additive component. Duplicate type of epistasis was evident by the presence of contrasting signs to [h] and [l] components.

4.3.4.4 Components of gene action for powdery mildew PDI in the six generations of the cross A.Jeet X IIHR 190-1.

Significant "t" values of scaling test A, B and C, and significant estimates of m, [d] and [h] components followed by highly significant chi square test all these indicated the inadequacy of additive - dominance model to explain inheritance of resistance to powdery mildew in the breeding line IIHR 190-1. Estimates of mean (m), additive [d], additive X additive [i] additive X dominance [j] were highly significant. Dominance [h] and dominance x dominance [l] were non-significant. Magnitude of additive component was larger than dominance component. Contrasting signs of [h] and [l] indicated the duplicate type of epistasis.

4.4 DISEASE DEVELOPMENTAL STUDY

Disease development is an interaction between host plants pathogen and environmental factors. Weather factors like temperature, humidity and rainfall greatly influence the infection, development and spread of the disease. A study was conducted to know the role of temperature, humidity and rainfall on the initiation and development of Alternaria leaf blight, downy mildew and powdery mildew on susceptible variety Arka Jeet. The results of this study are presented below.

4.4.1.1 Alternaria leaf blight.

Mean values of maximum and minimum temperatures, relative humidity (morning and evening) and increase in PDI are presented in the Table 21 and Figure 3. Disease initiation occurred in the first week of December, 40 days after sowing. During this period maximum temperature was 27.3° C, minimum temperature was 10.0° C with RH I (morning) at 58.7 per cent and RH II (evening) was 45.2 per cent. Maximum disease increase was observed during the later stages of crop growth. i.e. 40 days after infection when maximum temperature was 27.81° C, minimum temperature was 13.8° C, RH I (morning) was 64.0% and RH II (evening) was 48%. During final observations the disease development was 5.52 per cent during which period maximum temperature was 28.6° C, minimum temperature was 15.6° C, relative humidity I (morning) was 64.5 per cent and relative humidity II (evening) was 48.2 per cent.

4.4.1.2 Correlation studies

Correlation between maximum temperature minimum temperature, relative humidity I (morning), relative humidity II (evening) and Alternaria leaf blight development was analysed.

Alternaria leaf blight development was positively correlated with the maximum temperature but the relationship was statistically not significant (r = 0.0735). Minimum temperature was also related positively (0.4126) but relationship was non significant. In the similar way relative humidity I (morning) (r = 0.5800) and relative humidity II (evening) (r = 0.4546) were correlated positively with Alternaria leaf blight development but the results were statistically non significant.

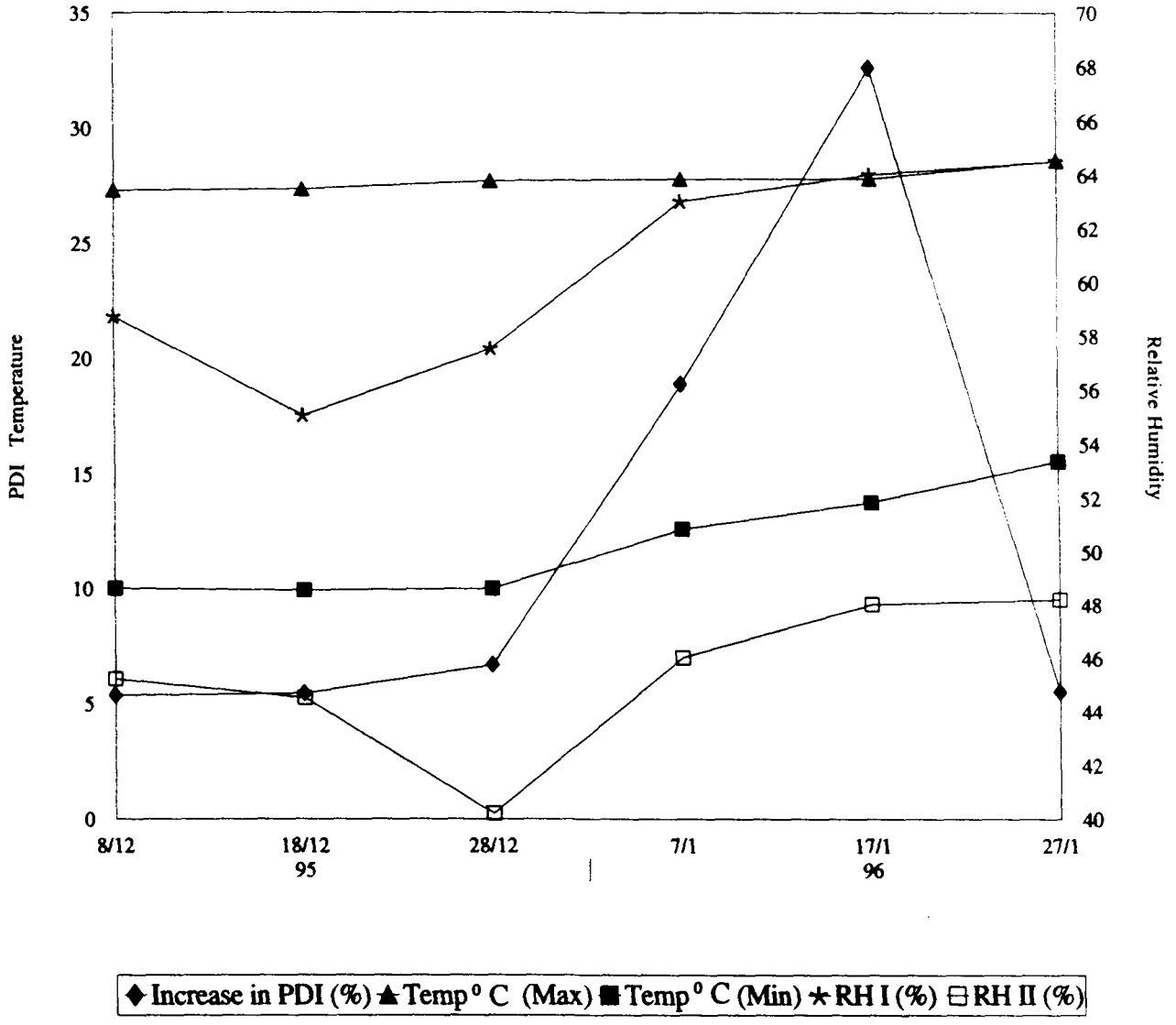
4.4.2.1 Downy mildew.

Mean values of maximum and minimum temperatures, relative humidity I (morning) and II (evening) and downy mildew development on Arka Jeet are pre-

Table 21 Weather parameters and Alternaria leaf blight development on Arka Jeet from December 1995 to January 1996

Dates	Increase in PDI	Temperature in ^{0} C		Relative humidity (%)	
		Max	Min	I	II
8/12	5.36	27.30	10.00	58.70	45.20
18/12	5.44	27.35	9.90	55.00	44.50
28/12	6.68	27.70	9.98	57.50	40.20
7/1	18.90	27.80	12.60	63.00	46.00
17/1	32.60	27.81	13.80	64.00	48.00
27/1	5.52	28.60	15.60	64.50	48.20

Fig. 3 Effect of weather parameters on development of Alternaria leaf blight development on Arka Jeet



sented in the table 22 and figure 4. Disease initiation occurred on 28th November when maximum temperature was 28.47° C, minimum 16.67° C with relative humidity 68.95 and 64.10 per cent respectively. Maximum disease increase was observed (24.24%) when maximum temperature was 27.68° C with 12.5° C as minimum and 62.84 and 45.65 per cent relative humidities.

4.4.2.2 Correlation study

Correlation between downy mildew development and minimum and maximum temperatures, relative humidity I and II are presented in the Table 24. Maximum temperature was positively correlated with downy mildew development (r=0.1522) but the relationship was statistically non significant. A negative non significant correlation was observed between minimum temperature and downy mildew development (r=0.1742). Relative humidity I (morning) was positively but non significantly correlated with downy mildew development. Again a positive but non significant relationship was established between downy mildew development and relative humidity II (evening) (r=0.1385)

4.4.3.1 Powdery mildew

Powdery mildew developed, maximum and minimum temperatures, relative humidity I (morning) and II (evening) and rainfall data for the period of September to october 1996 are presented in the Table 23 and Figure 5. Powdery mildew on Arka Jeet initiated on 30th September when temperature was 27.89° C with a minimum of 19.68° C. Relative humidity was moderately high (78.6% and 72.75% respectively) with an average rainfall of 2.26 mm. Maximum development was observed on 10th october when maximum temperature was 27.60° C, minimum temperature was 17.86° C with a low humidity of 75.30 per cent and 67.35 per cent. Rainfall during that period was nil. In tthe next observation, disease development was drastically reduced to 1 per cent. Corresponding maximum temperature was 26.63° C, minimum temperature was 18.83° C RH I (morning) was maximum (83.65%) also RH II (evening) (78.60%) with heavy rainfall (7.32mm).

Table 22 Weather parameters and Downy mildew development on Arka Jeet from November 1995 to January 1996

Dates	Increase in PDI	Temperature in ^{0}C		Relative humidity (%)	
		Max	Min	I	II
28/11	2.50	28.47	16.67	68.95	64.10
6/12	4.64	27.38	10.30	58.80	45.35
16/12	8.60	27.21	9.86	54.50	44.00
26/12	11.82	27.65	9.97	57.25	38.85
5/1	24.24	27.68	12.50	62.84	45.65
15/1	12.00	27.84	13.93	64.40	48.40
25/1	14.34	28.63	15.78	65.00	48.65

Fig. 4 Effect of weather parameters on development of Downy mildew development on Arka Jeet

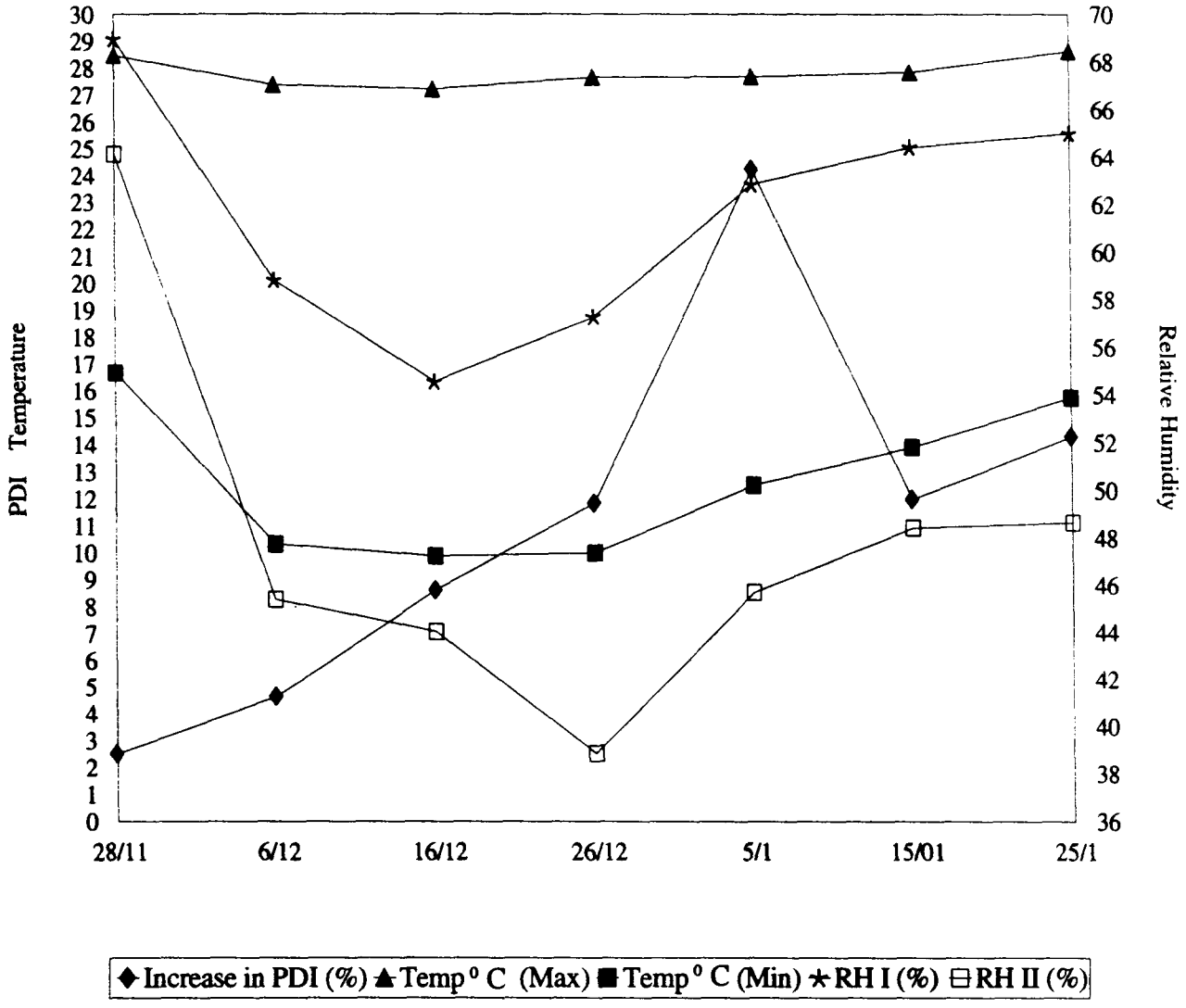
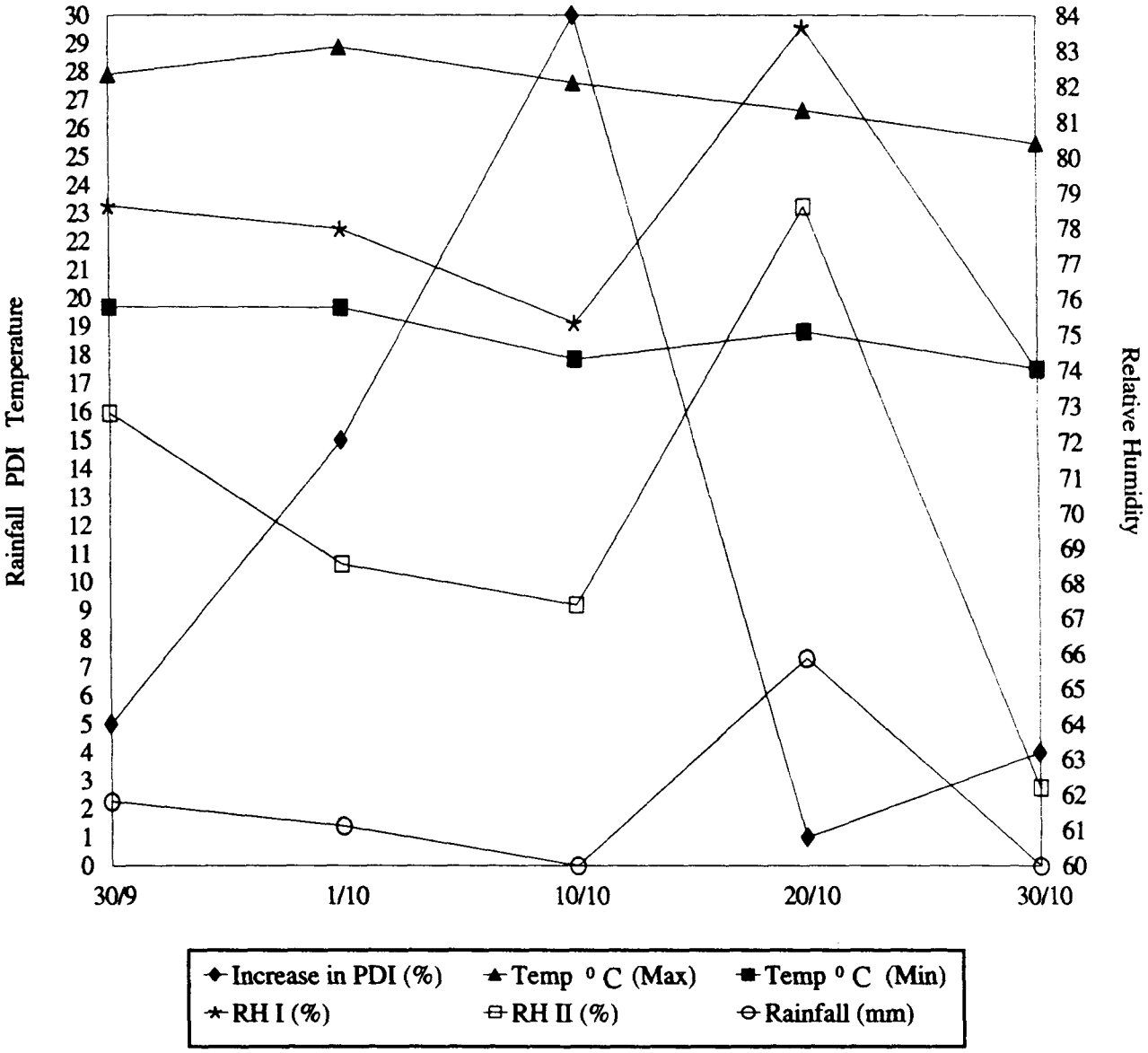


Table 23 Weather parameters and Powdery mildew development on Arka Jeet from November 1995 to January 1996

Dates	Increase in PDI	Temperature in ^{0} C		Relative humidity (%)		Rainfall (mm)
		Max	Min	I	II	
30/9	5.00	27.89	19.68	78.60	72.75	2.26
1/10	15.00	28.86	19.67	77.95	68.50	1.40
10/10	30.00	27.60	17.86	75.30	67.35	0.00
20/10	1.00	26.63	18.83	83.65	78.60	7.32
30/10	4.00	25.50	17.56	74.00	62.20	0.00

Fig. 5 Effect of weather parameters on development of Powdery mildew development on Arka Jeet



In the next observation PDI increased (4) where rainfall was nil and relative humidities were comparatively low (74.0% and 17.56^0 C respectively).

4.4.3.2 Correlation study

Correlation co-efficients between maximum and minimum temperatures, relative humidity I (morning) and II (evening) rainfall and powdery mildew development is presented in the Table 24. Maximum temperature was positively correlated with powdery mildew development on Arka Jeet (r = 0.2145) but the relation was non significant. Minimum temperature was negatively correlated to disease development but here also the relationship was non significant (r = -0.2403). A negative correlation was established among relative humidity I (morning) (r = -0.4562) and powdery mildew development. A significant and negative correlation between relative humidity II (evening) (r = -0.8711), rainfall (r = -0.8769) and powdery mildew development was observed.

4.5 DISEASE PROGRESS STUDY

4.5.1 Alternaria leaf blight

Disease progress data of resistant lines (IIHR 352a and IIHR 190-1) and susceptible variety Arka Jeet is presented in Table 25 and Figure 6. Maximum disease intensity was observed on Arka Jeet in all the observation compared to the two resistant lines. During intial observation, the highest PDI was recorded on Arka Jeet (5.3) compared to IIHR 352a (1.0) and IIHR 190-1 (1.2). The same trend followed for all the observations. In the last observation also Arka Jeet recorded a very high PDI (74.5) whereas PDI of IIHR 352a (10.87) and IIHR 190-1 (13.5) was well within the resistant category.

Table 24 Correlation studies with weather parameters for Alternaria leaf blight, downy mildew and powdery mildew on Arka Jeet

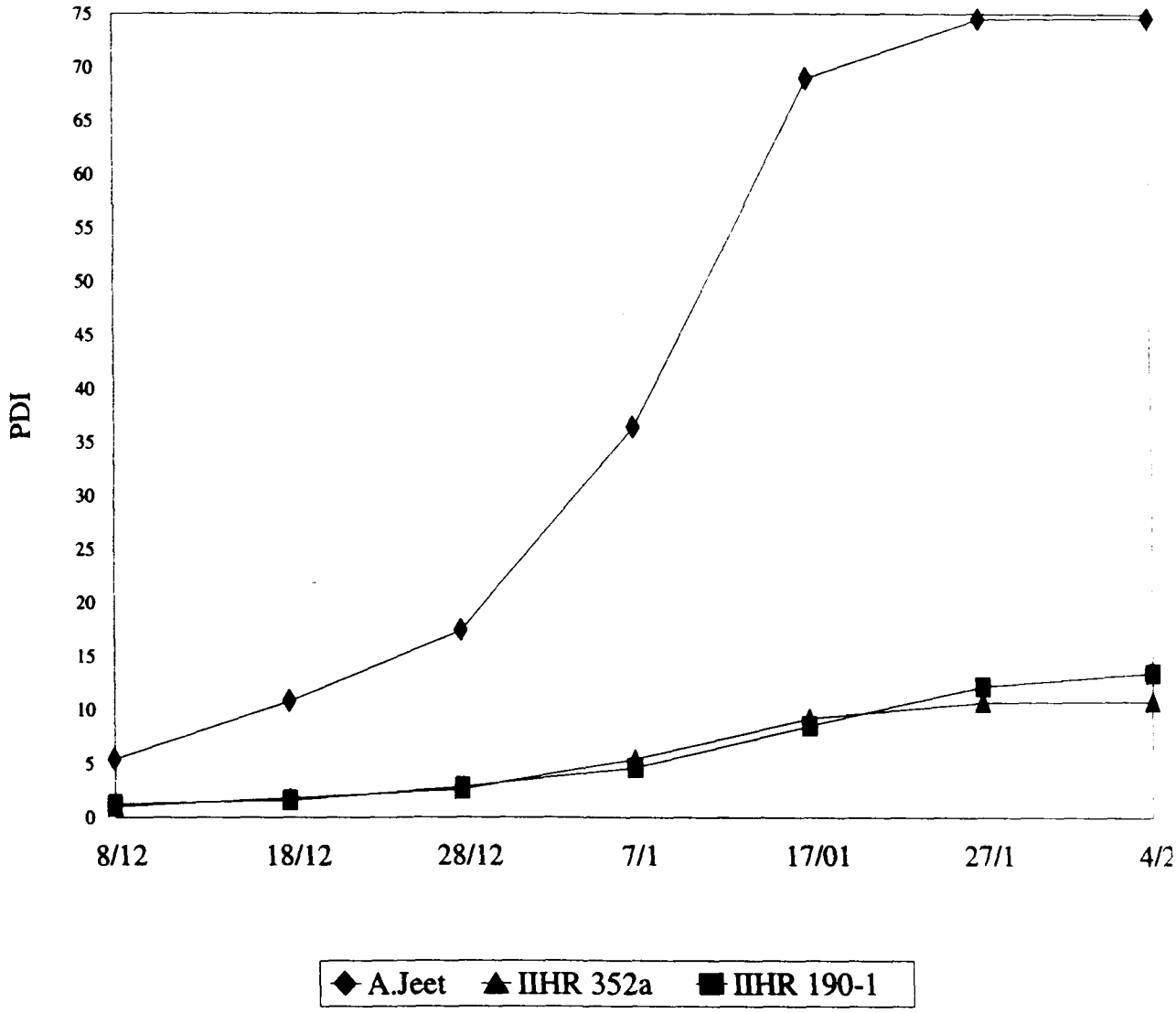
Weather parameters	Correlation coefficients		
	Alternaria leaf blight	Downy mildew	Powdery mildew
Max. temperature	0.0735	0.1522	0.2145
Min. temperature	0.4126	0.1742	-0.2403
Relative humidity I	0.5800	0.1293	-0.4562
R. Humidity II	0.4546	0.1385	-0.8711*
Rainfall	-	-	-0.8769*

* Significance at 5%

Table 25 Alternaria leaf blight disease progress in resistance and susceptible lines

Dates	Arka Jeet	IIHR 352a	IIHR 190-1
8/12	5.36	1.0	1.2
18/12	10.8	1.8	1.6
28/12	17.4	2.6	2.8
7/1	36.4	5.4	4.6
17/1	68.9	9.2	8.5
27/1	74.5	10.7	12.2
4/2	74.5	10.7	13.5

Fig.6 Alternaria leaf blight disease progress curve



4.5.2 Downy mildew

Disease progress data of resistant and susceptible parents are presented in the Table 26 and Figure 7. Maximum PDI and faster growth was observed in the susceptible variety Arka Jeet compared ti resistant lines. At the final observation, IIHR 352a (14.8) and IIHR 190-1 (16.4) were well within the resistant category while the PDI of Arka Jeet was maximum (78.14) and grouped under highly susceptible group.

4.5.3 Powdery mildew

Disease progress data at an interval of 10 days for powdery mildew PDI on resistant and susceptible lines is presented in Table 27 and Figure 8. Resistant parents showed a very slow growth of powdery mildew. Even in the last observation PDI of IIHR 352a (1.7) and IIHR 190-1 (1.9) was very low. Arka Jeet a susceptible variety recorded a very high PDI in the last observation (60.5).

4.6 SPORULATION STUDY

Growth and development of pathogen on resistant and susceptible lines vary to a great extent. Susceptible line provides required nutrients for the growth and abundant sporulation of the pathogen whereas in resistant lines, there is a partial supression of the growth of the pathogen. Results of sporulation studies conducted on the resistant and susceptible lines when infected with Alternaria leaf blight, downy mildew and powdery mildew are presented below.

4.6.1 Alternaria leaf blight.

Conidial concentration of Alternaria leaf blight varied significantly between susceptible and resistant parents (Table 28). Susceptible parent Arka Jeet recorded significantly higher conidial concentration (41.17×10^4) per centimeter square of leaf

Table 26 Downy mildew disease progress in resistance and susceptible lines

Dates	Arka Jeet	IIHR 352a	IIHR 190-1
28/11	2.5	1.2	1.0
6/12	7.1	3.2	2.5
16/12	15.7	5.8	4.2
26/12	37.6	8.3	7.8
5/1	51.8	13.6	14.5
15/1	63.8	14.2	15.1
25/1	78.1	14.8	16.4

Fig. 7 Downy mildew disease progress curve

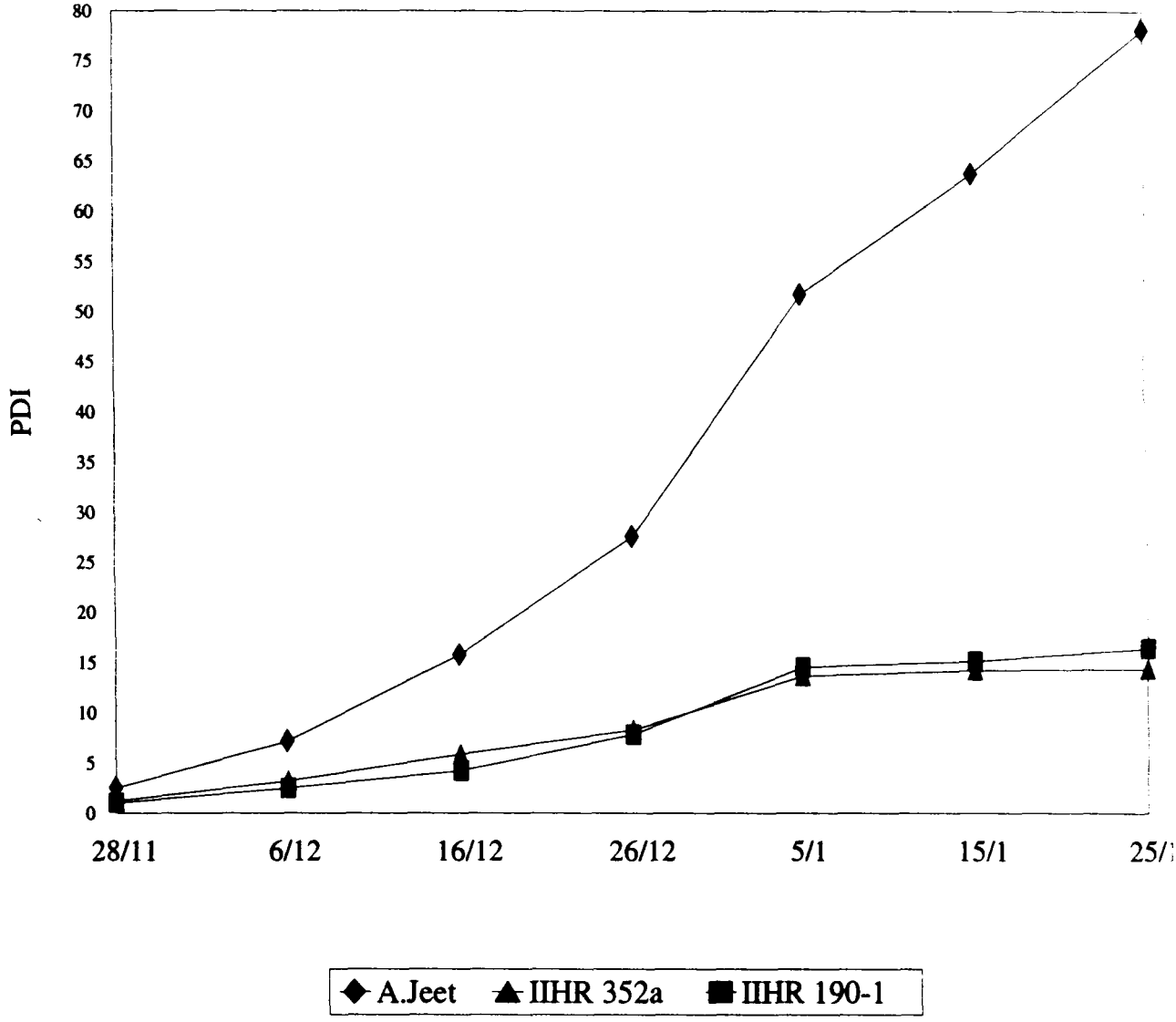


Table 27 Powdery mildew disease progress in resistance and susceptible lines

Dates	Arka Jeet	IIHR 352a	IIHR 190-1
30/9	5	0	0
1/10	20	0.5	0.6
10/10	55.2	1.2	1.8
20/10	56.1	1.2	1.8
30/10	60.5	1.7	1.9

Fig. 8 Powdery mildew disease progress curve

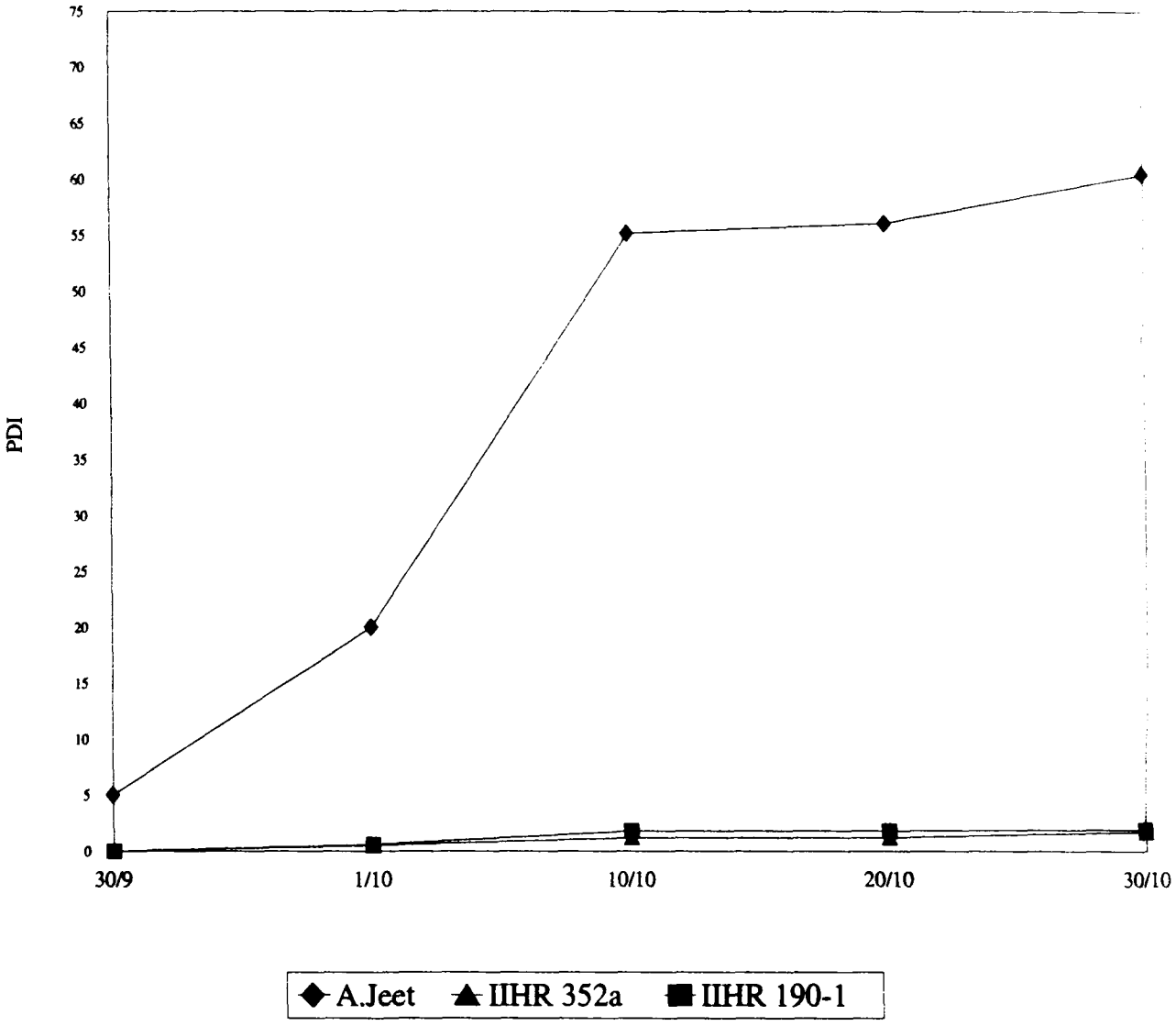


Table 28 Mean concentration of conidia in Alternaria leaf blight affected resistant and susceptible lines

Lines	Conidia concentration (X 10^4/cm2)	Comparitive reduction with Arka Jeet (%)
Arka Jeet	41.17[a]	-
IIHR 352a	15.50[b]	66.42
IIHR 352b	17.50[b]	62.09
IIHR 352c	15.83[b]	65.71
IIHR 190-1	15.67[b]	66.06
F test	**	
S.Ed	1.78	
C.D	3.49	

area. There was no significant differences among the resistant parents. Resistant parent IIHR 352a had a significantly lower spore concentration (15.50 X 10^4/cm^2) than the susceptible variety Arka Jeet but it was at par with IIHR 190-1 (15.67 X 10^4/cm^2), IIHR 352c (15.83 X 10^4/cm^2) and IIHR 352b (17.5 X 10^4/cm^2).

The comparative reduction in spore concentration of resistant parents with that of susceptible parent ranged from 62.09% (IIHR 352b) to 66.42% (IIHR 352a).

4.6.2 Downy mildew

Resistant and susceptible parents differed significantly for zoospore concentration per centimeter square area. (Table 29) Resistant parent IIHR 352c recorded significantly lower concentration of zoospores (39.50 X 10^4/cm^2) than the susceptible variety Arka Jeet but it was on par with the spore concentration of IIHR 352b (40.33 X 10^4/cm^2), IIHR 352a (42.83 X 10^4/cm^2) and IIHR 190-1 (44.67 X 10^4/cm^2). Significantly higher spore concentration was recorded in the susceptible variety Arka Jeet (124.67 X 10^4/cm^2).

There was a reduction in spore load in the range of 64.17% (IIHR 190-1) to 68.32% (IIHR 352c) when compared to susceptible parent Arka Jeet

4.6.3 Powdery mildew

Concentrations of conidia differed significantly among the resistant and susceptible parents. (Table 30) Susceptible variety Arka Jeet recorded a significantly higher spore concentration (67.33 x 10^4/cm^2) than the resistant parents. Resistant parent IIHR 352a had a significantly lower conidial concentration (16.33x10^4/cm^2) than the susceptible variety Arka Jeet but this concentration was statistically on par with the conidial concentration of IIHR 352c (16.53 X 10^4/cm^2) IIHR 352b (17.0 X 10^4/cm^2) and IIHR 190-1 (20.14 X 10^4/cm^2).

Table 29 Mean concentration of zoospores in downy mildew affected resistant and susceptible lines

Lines	Conidia concentration (X 10^4/cm2)	Comparitive reduction with Arka Jeet (%)
Arka Jeet	124.67[a]	-
IIHR 352a	42.83[b]	65.64
IIHR 352b	40.33[b]	67.65
IIHR 352c	39.50[b]	68.32
IIHR 190-1	44.67[b]	64.17
F test	**	
S.Ed	2.76	
C D	5.41	

Table 30 Mean concentration of conidia in powdery mildew affected resistant and susceptible lines

Lines	Conidia concentration (X 10^4/cm2)	Comparitive reduction with Arka Jeet (%)
Arka Jeet	67.33[a]	
IIHR 352a	16.33[b]	75.74
IIHr 352b	17.00[b]	74.75
IIHR 352c	16.53[b]	75.44
IIHR 190-1	20.14[b]	70.08
F test	**	
S.Ed	2.2	
C.D	4.42	

Reduction in spore concentration when compared to susceptible parent was maximum in IIHR 352a (75.74%) followed by IIHR 352c (75.44%) and IIHR 352b (74.75%) lowest reduction of 70.08% was observed in the resistant parent IIHR 190-1.

4.7 BIOCHEMICAL ANALYSIS

Biochemical constituents such as total sugars reducing sugars, non-reducing sugars, starch and total phenols are reported to have an influence on the resistance of plants to diseases. Phenols are reported to hinder the establishment and development of pathogen on the plants. Keeping this factor in view, studies were conducted to quantify the total sugars, reducing sugars, non-reducing sugars, starch and total phenol content of resistant and susceptible parents before and after infection with the downy mildew fungus. The results of these studies are presented below.

4.7.1 Total sugar content of resistant and susceptible parents before and after infection with downy mildew.

Resistant and susceptible parents differed significantly for total sugar content with and without infection by downy mildew fungus (Table 31). Before infection total sugar content was maximum in the resistant parent IIHR 190-1 (34.5 mg) which was on par with that of IIHR 352a (33.10mg). The lowest total sugar content was recorded in the susceptible parent Arka Jeet (20.09mg).

When analysis were carried out after infection with downy mildew, total sugar content increased in all the parents. IIHR 352a had shown the maximum content off 39.9mg followed by susceptible parent Arka Jeet (37.52mg) and IIHR 352c (37.42mg). The lowest sugar content was recorded in the resistant parent IIHR 352b (33.90mg) which was significantly lower than other parents.

Table 31 Total sugar content (mg/100g) of resistant and susceptible parents as influenced by downy mildew

Parents	PDI	Total sugar content		
		Without infection	With infection	Per cent increase
Arka Jeet	76.13	20.09	37.52	86.75
IIHR 352a	8.11	33.10	39.90	20.54
IIHR 352b	5.27	29.56	33.90	12.80
IIHR 352c	4.65	29.64	37.42	26.24
IIHR 190-1	6.79	34.50	36.69	6.34
F test	**	**	**	**
S.Ed	1.73	0.82	0.84	1.15
C.D	3.98	1.67	1.88	2.65

When per cent increase in sugar content after infection was studied, susceptible parent Arka Jeet showed the maximum increase of 86.75 per cent which was significantly higher than all the resistant parents. Resistant parent IIHR 190-1 showed the least increase (6.34%) in total sugar content after infection. In the remaining resistant parents the increase ranged from 12.80 per cent (IIHR 352b) to 26.24 per cent (IIHR 352c).

4.7.2 Reducing sugar content of susceptible and resistant parents before and after infection with downy mildew fungus.

Before infection, there was no significant differences among resistant and susceptible parents. Resistant line IIHR 190-1 recorded the highest reducing sugar content (24.35mg) and it was the lowest in susceptible parent Arka Jeet (11.93mg) as presented in Table 32.

After infection, reducing sugar content of the resistant and susceptible parents differed significantly with each other. Reducing sugar content of all the resistant parents reduced after infection, whereas it increased in case of susceptible parent. Arka Jeet recorded the maximum reducing sugar content of 21.07mg which was on par with that of IIHR 352a (20.76mg). The lowest reducing sugar content was recorded in the resistant parent IIHR 352c (14.23 mg).

Per cent change in reducing sugar content differed significantly in the resistant and susceptible parents. Arka Jeet showed a maximum increase of 76.61 per cent. In all the resistant parents the change is in the negative direction. The lowest reduction in reducing sugar content was recorded in IIHR 352a (-7.65%) which was on par with IIHR 352b (-11.91%). Maximum reduction was observed in the resistant parent IIHR 190-1 (-18.53%) which was on par with that of IIHR 352c (-15.64%).

Table 32 Reducing sugar content (mg/100g) of resistant and susceptible parents as influenced by downy mildew

Parents	PDI	Reducing sugar content		
		Without infection	With infection	Per cent change
Arka Jeet	76.23	11.93	21.07	76.61
IIHR 352a	8.11	22.48	20.76	-7.65
IIHR 352b	5.27	20.81	18.33	-11.91
IIHR 352c	4.65	16.87	14.23	-15.64
IIHR 190-1	6.79	24.35	19.83	-18.56
F test	**	N.S	**	**
S.Ed	1.73	4.85	0.82	1.73
C.D	3.98	-	1.68	3.98

4.7.3 Non reducing sugar content of susceptible and resistant parents before and after infection with downy mildew.

Parents and hybrids differed significantly for non-reducing sugar content before and after infection with downy mildew (Table 33). Before infection, non-reducing sugar content was significantly higher in the resistant parent IIHR 352c (12.77mg). Susceptible parent Arka Jeet recorded the lowest content (8.16mg) which was significantly lower than other resistant parents except IIHR 352b (8.74mg).

After infection, non reducing sugar content increased in all the parents. Significantly higher non reducing sugar content was recorded in the resistant parent IIHR 352c (23.19mg). Least content of non reducing sugar was recorded in the resistant parent IIHR 352b (15.66mg) which was on par with that of Arka Jeet (16.45) and IIHR 190-1 (16.87mg).

Significantly higher magnitude of increase of non reducing sugar content after infection was observed in the susceptible parent Arka Jeet (101.59%) followed by IIHR 352c (81.59%) and IIHR 352b (79.19%). Lowest increase was observed in the resistant parent IIHR 190-1 (66.37%).

4.7.4 Starch content of susceptible and resistant parents before and after infection with downy mildew

Starch content of resistant and susceptible parents did not differed significantly with or without downy mildew infection (Table 34). Before infection starch content was maximum in the resistant parent IIHR 352c (1.16mg) and was the lowest in resistant parent IIHR 352b (0.92mg).

After infection, starch content increased in all the parents. Maximum starch content recorded in the resistant parent IIHR 352a and IIHR 352b (1.55mg) and the lowest content was recorded in the susceptible parent Arka Jeet (1.31mg).

Table 33 Non reducing sugar content (mg/100g) of resistant and susceptible parents as influenced by downy mildew

Parents	PDI	Non reducing sugar content		
		Without infection	With infection	Per cent increase
Arka Jeet	76.13	8.16	16.45	101.59
IIHR 352a	8.11	10.65	18.62	74.83
IIHR 352b	5.27	8.74	15.66	79.17
IIHR 352c	4.65	12.77	23.19	81.59
IIHR 190-1	6.79	10.14	16.87	66.37
F test	**	**	**	**
S.Ed	1.73	0.92	0.95	1.73
C.D	3.98	1.83	1.92	3.98

Table 34 Starch content (mg/100g) of resistant and susceptible parents as influenced by downy mildew

Parents	PDI	Starch content	
		Without infection	With infection
A. Jeet	76.23	1.08	1.31
IIHR 352a	8.11	1.10	1.55
IIHR 352b	5.27	0.92	1.55
IIHR 352c	4.65	1.16	1.54
IIHR 190-1	6.79	1.01	1.37
F test	**	N.S	N.S
S.Ed	1.73	0.77	0.82
C.D	3.98	-	-

4.7.5 Total phenol content before and after infection with downy mildew in resistant and susceptible parents.

Significant differences were observed for the total phenol content of resistant and susceptible parents both before and after infection (table 35). Before infection significantly higher total phenol content was recorded in the resistant parent IIHR 352a (131.2mg). This was followed by resistant parent IIHR 190-1 (123.78mg) which was on par with IIHR 352b (121.60mg) and IIHR 352c (121.42mg). Significantly lower total phenol content was recorded in the susceptible parent Arka Jeet (98.30mg).

Infection of downy mildew increased the total phenol content in all the parents. Resistant parent IIHR 190-1 recorded significantly higher total phenol content (175.52mg) followed by IIHR 352a (154.17mg). Total phenol content of IIHR 352b (147.67mg) and IIHR 352c (145.00mg) were on par with each other. Susceptible parent Arka Jeet recorded the lowest total phenol content of 105.55mg after infection.

When per cent increase in total phenol content after infection was studied, IIHR 190-1 (41.79%) showed a significantly higher increase than other parents. This was followed by IIHR 352b (21.59%). Increase in phenol content was on par in the parents IIHR 352a (17.5%) and IIHR 352c (19.42%). The lowest increase was recorded in the susceptible parent Arka Jeet (7.35%) which was significantly lower than all the resistant parents.

Table 35 Total phenols content (mg/100g) of resistant and susceptible parents as influenced by downy mildew

Parents	PDI	Total phenols content		
		Without infection	With infection	Per cent increase
Arka Jeet	76.23	98.30	105.53	7.35
IIHR 352a	8.11	131.20	154.17	17.5
IIHR 352b	5.27	121.60	147.67	21.59
IIHR 352c	4.65	121.42	145.00	19.42
IIHR 190-1	6.79	123.78	175.52	41.79
F test	**	**	**	**
S.Ed	1.73	2.3	2.28	1.15
C.D	3.98	4.7	4.5	2.65

4.7.6 Correlation between total sugar, reducing sugar, non reducing sugar, starch, total phenol content and downy mildew resistance.

Correlation between total sugar content, reducing sugar, non-reducing sugar, starch, total phenol and downy mildew incidence was worked out (Table 36).

Total sugar content was positively correlated with the incidence of downy mildew (r = 0.5210) but the correlation was not significant. Positive and non-significant correlation was also observed between downy mildew incidence and reducing sugar content (r = 0.1358).

Non-reducing sugar and starch content were negatively correlated with downy mildew incidence with correlation coefficient r = -0.228 and r = -0.5592, but the correlation was not significant.

A negative and highly significant correlation was observed between downy mildew incidence and total phenol content of the parents (r = -0.9015).

Table 36 Correlation between biochemical constituents of resistant and susceptible parents and downy mildew disease intensity

Biochemical constituents	Correlation coefficients
Total Sugar	0.5210
Reducing Sugar	0.1358
Non-reducing Sugar	-0.2280
Starch	-0.5592
Total phenols	-0.9015**
Value at 5% 2.447	
1% 3.707	
* Significant at 5%	
** Significant at 1%	

DISCUSSION

V DISCUSSION

Muskmelon (*Cucumis melo*) is one of the most important vegetable crops grown through out the world. Alternaria leaf blight, downy mildew and powdery mildew are the three major diseases of cucurbits in general and muskmelon in particular which cause major economic loss to the muskmelon growers (Jaggar, 1926, Grewal and Mathur, 1964, and Vardy and Ducort, 1985). Chemical control has limited success owing to the high cost involved and ability of the pathogens to develop resistance to chemicals.

Development of cultivars with inherent resistance to these diseases is one of the most effective, cheap and eco-friendly means of controlling Alternaria leaf blight, downy mildew, and powdery mildew on muskmelon. Many workers have screened muskmelon germplasm for resistance to Alternaria leaf blight, downy mildew, and powdery mildew and reported various sources of resistance (Swamy *et al.* 1980, Thomas and Webb, 1981, Amin *et al.* 1982, Cohen and Eyal, 1987).

In India no variety with combined resistance to Alternaria leaf blight, downy mildew, and powdery mildew have been bred or released commercially. Information on genetic analysis on resistance would be useful in planning and execution of breeding methods to develop resistant varieties. Keeping this in mind, present study of genetics of resistance to Alternaria leaf blight, downy mildew, and powdery mildew was undertaken to analyse the genetics of resistance along with the correlations between weather parameter and biochemical compositions with disease development.

5.1 ALTERNARIA LEAF BLIGHT RESISTANCE.

5.1.1 Variability, heritability and genetic advance.

Existence of variability for desirable characters in the base population is an essential parameter in crop improvement programs. In the present study phenotypic

and genotypic variances were high for PDI in the F_2 generations of all the crosses. This indicated the scope for selection of suitable initial material in breeding for further improvement. The difference among the F_2 generations of the different crosses could be attributed to the difference in genetic constitution of their parents.

Though the range of values reflects the extent of phenotypic variability in respect of PDI it includes genotypic, environmental and genotypic x environmental interactions. Therefore an assessment of heritable and non heritable components in the total variability observed is necessary. The heritable portion of the overall variation can be ascertained by studying the components of variation such as coefficient of genotypic variability, heritability and genetic advance. Phenotypic coefficient of variation indicated only the extent of variability present in PDI and does not indicate the heritable portion. This could be ascertained from the heritability estimates which in broad sense includes both additive and non-additive gene effects (Hanson *et al.* 1956) and in narrow sense includes only additive components (Lush, 1949).

The knowledge about heritability is useful in assessing the merits and demerits of a particular trait and it enables the plant breeder to decide the course of selection procedure to be followed under a given situation. In the present study heritability estimates in broad sense and narrow sense were calculated.

The heritability estimates (both broad sense and narrow sense) were high for PDI in the F_2 generations of all the crosses. It indicated the high magnitude of aditive gene action.

Though heritability estimates represent relative genetic strength of a character and indicated the efficiency of selection system, still their scope is restricted as they are prone to change in the envirnoment, materials etc. (Hanson, *et al.,* 1956). Hence use of heritability values coupled with genetic advance would be more reliable than heritability alone. (Johanson, *et al.*, 1955) which will be helpful in forming selection procedures. In the present study high heritability along with moderate genetic advance was observed for PDI in F_2 generations of all the crosses, suggesting the variation

was due to both additive and non additive gene action. Hence selection for these character could be useful. High genotypic coefficient of variation and high heritability coupled with a greater genetic advance would be responsive to selection in positive direction. High heritability estimates for Alternaria leaf blight resistance was reported by Boyhan and Norton (1992) in muskmelon, Vieira *et al.* (1991) and Boiteurs *et al.* (1993) in carrot.

5.1.2 Genetics of Alternaria leaf blight resistance.

Oligogenic and polygenic are the two types of resistance recognised in parasitic system. Oligogenic resistance is generally characterised by pathogen specificity with complete resistance where as polygenic resistance varies continuously over varieties and it rarely approaches complete resistance or immunity. The data on Alternaria leaf blight resistance of the F_2 generation plants showed continuous variation. Since the Alternaria leaf blight resistance is considered as quantitative trait, it depends upon gene differences at many loci, the effects of which are not individually distinguishable, Mendelian ratios were not be observed and hence Mendelian way of analysis is not appropriate to deal with such segregation patterns. A clearly different biometrical approach is needed to partition, interpret and make predictions about such variations. This suggested to use biometrical technique - six generation mean analysis to determine nature and magnitude of gene effects. The greatest merit of generation mean analysis lies in the estimate of gene effects, viz additive [d], dominance [h], additive X additive [i], additive X dominance [j] and dominance X dominance [l]. Besides it is simpler and statistically reliable method to decipher the nature and magnitude of gene action involved in the inheritance of quantitative traits.

5.1.2.1 Six generation mean analysis

The PDI estimates of all the resistant parents was with in the grouping of resistant category and susceptible parent Arka Jeet was in the highly susceptible category which indicated that the parents are homozygous for their disease reaction and lower variances showed that there was no segregation among the parental lines and parental materials are stable.

In all the crosses where one of the parent was resistant, the mean PDI of F_1 generations was observed to be with in the ratings of resistant parent which indicated that the resistance to Alternaria leaf blight is predominantly under the control of dominant gene action.

The F_2 means of all the crosses were within the range of moderately resistant category. This indicates progenies produced by selfing F_1 generations are not influenced by genic distribution between the parental lines which produced them. Significant additive gene effects were negative in all the crosses which played an important role in reducing the PDI value.

Mean PDI values of B_1 generations in all the crosses except the cross IIHR 352a X A Jeet during October 1995 were with in the resistant category. The B_1 of IIHR 352a X A Jeet was also more inclined towards resistant category. This indicates that the (P_1) bears all the genes with decreasing effects on PDI where as F_1 also possesses all the genes with decreasing effects on PDI, so the resulting B_1 generation expresses relatively higher level of resistance.

In B_2 generations the mean PDI was with in the moderately resistant category or more close to moderately resistant category (in cross A. Jeet X IIHR 352a and A. Jeet X IIHR 352c) which suggest one of the susceptible parent (P_2) bears all the genes with increasing effect on PDI in low magnitude and the F_1 possesses all the genes with decreasing effects on PDI in higher magnitude than P_2.

Higher variance in F_2 generations of all the crosses revealed that the resistance is governed by more than one genes as evidenced by continuous distribution of disease severity.

5.1.2.2 Gene action

Inadequacy of additive - dominance model to explain inheritance of Alternaria leaf blight resistance in muskmelon was indicated by the significance of scaling tests.

This was further supported by the joint scaling test of Cavalli and highly significant chi square value in all the crosses. This necessiciated to include digenic epistatic gene effects to explain the observed variations in generation means for PDI of Alternaria leaf blight in different crosses.

In the present study, additive, dominance, additive X additive, additive X dominance and dominance X dominance gene effects were found to contribute to the inheritance of resistance.

All the crosses showed higher magnitude of dominance effect than additive effects. The additive effects were negative indicating their reinforcement effect on resistance. Epistatic gene effect of additive X dominance was significant in the cross A. Jeet X IIHR 352a during october 1995 but the magnitude was low. Interaction of additive X additive genes was high and significant during october 1995 in the cross A. Jeet X IIHR 190-1. The complementary type of epistasis was more pronounced in all the cross except the cross A. Jeet X IIHR 190-1 where duplicate type of epistasis was found. Complementary type of epistasis indicated the similar direction of action of dominance and dominance X dominance interaction and in our study the sign was negative which indicated the decreasing effect on PDI. Duplicate epistasis in the cross A. Jeet X IIHR 190-1 indicated that dominance and dominance X dominance effects are in opposite direction but in our study dominance X dominance component was non significant whereas dominance component was highly significant and negative in direction.

The significant negative additive and additive X additive gene effects in the cross A. Jeet X IIHR 352a and A. Jeet X IIHR 190-1 and significant additive gene effects in A. Jeet X IIHR 352b and A. Jeet X IIHR 352c indicated these crosses are promising as resistance would be fixable by selection in advanced progenies and there is a possibility of transgressive segregation in advanced generations however dominance gene effect cannot be neglected.

Significant negative dominance gene effects in the cross A. Jeet X IIHR 352a, A. Jeet X IIHR 352b and A. Jeet X IIHR 352c and significant dominance and dominance X dominance effect in A. Jeet X IIHR 190-1 indicates the usefulness of heterosis breeding but additive gene effect cannot be ignored.

Thus the results obtained revealed that both additive and non-additive gene effects are important and non additive gene action is predominant. Our study is in accordance with that of Boyhan and Norton (1992) who reported significant additive and additive x dominance gene action for Alternaria leaf blight resistance in muskmelon. Manjunath (1994) observed a high dominance gene action for alternaria leaf blight resistance in carrot.

The presence of diversity of interaction in different crosses indicated more than one gene is involved in the inheritance of resistance to Alternaria leaf blight in muskmelon.

Such a polygenic dominant resistance to Alternaria leaf blight was also reported by several workers who studied the genetics of resistance to Alternaria blight in different crops viz Gardner (1984), Martin and Heperly (1987) and Maicro *et al.* (1989) in tomato and Stavely (1975) in tobacco. In contrast Thomas *et al.* (1990) reported the monogenic dominance of resistance to Alternaria leaf blight in muskmelon.

The presence of significant amounts of gene action, additive, dominance and epistasis indicates that a breeding program relaying on reciprocal recurrent selection would result in progress towards breeding muskmelon resistant to Alternaria leaf blight.

5.2 DOWNY MILDEW RESISTANCE

5.2.1 Variability study.

In the present study considerable variability was observed for downy mildew PDI in the F_2 generations of the different crosses. This variability could be exploited for selection in the subsequent generations. The heritable portion of the total variability i.e. genotypic coefficient of variability and heritability were calculated to know the worth of the population. The narrow difference between G.C.V and P.C.V showed the little effect of environmental factor in the expression of resistance in these population. Heritability estimates in broad sense was very high for all the crosses. This heritability estimate includes both additive and non-additive components. The narrow sense heritability which speaks only of additive component was lower than the broad sense heritability indicating the presence of both additive and non additive gene actions.

Genetic advance for all the crosses were moderate. This moderate genetic advance coupled with high heritability estimates suggested that the variation was due to both additive and non additive gene action. Hence selection for these character could be useful.

5.2.2 Genetics of downy mildew resistance

The data on per cent disease index of downy mildew showed continuous variation in the segregating population. Mendalian genetics is not much useful in analysing such kind of data. Hence a different biometrical approach of six generation mean analysis was applied to know the magnitude and direction of different components of gene action.

5.2.2.1 Generation mean analysis.

Mean values of resistant parents for PDI was well within the range of resistant group while that of susceptible parent Arka Jeet was in the susceptible group indicating the true breeding nature of parents which was further supported by low variance observed in these populations.

In the F_1 progenies, where one of the parents in all the crosses was resistant to downy mildew, the mean PDI was well within or very close to resistant category. This indicated the resistance to downy mildew was dominant over susceptibility.

The F_2 means of the cross A.Jeet X IIHR 190-1 in october 1995 and A.Jeet X IIHR 190-1 were with in the resistant group while the means of other crosses though come under moderately resistant group, more inclined towards resistant group. This indicates progenies produced by selfing F_1 generations are not influenced by genic distribution between the parental strains which produced them. This also could be due to the significant and negative additive gene action in all the crosses which increases resistance.

B_1 generations of all the crosses were in the resistant category except A. Jeet X IIHR 190-1 which also inclined more towards resistant grouping. This indicated the decreasing effect of genes both in resistant parent and F_1 on PDI.

B_2 generations of all the crosses except A.Jeet X IIHR 352b were in susceptible category. This indicates the magnitude of genes with increasing effect on per cent disease index shared by susceptible parent was more than the magnitude of genes with decreasing effect on PDI shared by resistant F_1 generation whereas in the B_2 generation of the cross A,Jeet X IIHR 352b the mean PDI value was within the moderately resistant category which suggested the higher magnitudes of F_1 genes which reduces the PDI than that of the susceptible parent Arka Jeet.

Higher variance in the F_2 generations of all the crosses revealed that the resistance is governed by more than one gene as evidenced by continuous distribution of disease severity.

5.2.2.2 Gene actions

Significant deviations of Mather's scaling test, and joint scaling tests from zero indicated the inadequacy of additive - dominance model in explaining the inheritance of resistance to downy mildew in muskmelon. After this perfect fit solution was fitted to estimate the magnitude and direction of the digenic interaction effects for all the crosses.

Additive gene effect in all the crosses was significant and negative which indicates the reinforced effect on reducing the PDI. Among the interactions additive X additive, and additive X dominance gene effects were significant in all the crosses where as in the cross A. Jeet X IIHR 190-1 all the interactions were significant. Epistatic gene effect of dominance x dominance was significantly higher in two crosses A. Jeet X IIHR 352a and A. Jeet X IIHR 190-1 during April 1996. In these two crosses additive gene effects were also important. Hence, biparental approach inter se crossing and or reciprocal recurrent selection in the segregating generations of these crosses would be effective in improving this trait. Because these methods exploit both additive and non additive gene action involved in the expression of disease resistance. In the cross A. Jeet X IIHR 352b , additive gene action was significantly higher and negative. The epistatic effect of additive X additive and additive X dominance were also significant in this cross but they are positive in direction. Type of epistasis involved was complementary and additive genes seem to play greater role in the inheritance of this disease resistance.

Additive, dominance and additive X dominance components were significant in the cross A. Jeet X IIHR 352c . Additive and dominance components were negative where as additive x dominance component was positive but very low in magnitude. Here also complementary type of epistasis was observed. Both additive

and non-additive components were found to control resistance in this line with predominance of additive component. Recurrent selection will help in improving disease resistance in this strain.

Thus both additive and non additive gene effects were predominant in these crosses and additive gene action is pronounced. This indicated the inadequacy of mendalian genetics and strengthen the hypothesis of more than one gene control of resistance to downy mildew in muskmelon.

Jenkins (1946) also reported the polygenic nature of resistance to downy mildew in muskmelon. Anashenko (1980) reported three dominant genes for downy mildew resistance in sunflower and Moss *et al.* (1988) proposed three genes for downy mildew resistance in cauliflower.

However majority of works on muskmelon only fitted the ratio without analysing generation means, reported two incompletely dominant genes for resistance in muskmelon (Cohen *et al*, 1985, Thomas *et al.* 1988, Keningsch and Cohen, 1989 and in 1992). Cohen and Cohen (1986) reported a single incompletely dominant gene for downy mildew resistance.

A breeding program like recurrent selection which exploits both additive and non-additive components of gene action would be useful in improving these resistant sources as the additive, dominance and epistatic effects were significant and high in magnitude in all the crosses.

5.3 POWDERY MILDEW RESISTANCE

5.3.1 Variability study.

F2 generations of all the crosses showed high variability for powdery mildew PDI. Phenotypic and genotypic variances were very high. This indicated the scope for selection of suitable initial material in breeding for further improvement.

The coefficients of genotypic variaton (GCV) and phenotypic variation (PCV) were high for PDI in the F_2 generations of all the crosses. To ascertain heritable component of variability, heritability in broad sense and narrow sense was estimated.

The heritability in broad sense was high in all the crosses. Similar findings were reported for heritability of powdery mildew resistance on muskmelon by Shivakami *et al* (1979).

Narrow sense heritability which represent the additive component of heritability was lower than the broad sense heritability indicating the presence of both additive and non additive gene actions.

Genetic advance was moderate in all the crosses which also indicate the presence of additive as well as non additive gene action. High heritability coupled with moderate genetic advance would be responsive to selection in positive direction.

5.3.2 Genetics of powdery mildew resistance

Per cent disease index for powdery mildew in segregating generations varied continuously. So Mendalian genetics is of little use in understanding the mode of inheritance of resistance to powdery mildew in muskmelon. Analysing through generation mean analysis in the present studies provided the magnitude and direction of different gene actions.

5.3.2.1 Generation mean analysis.

Mean PDI for powdery mildew was very low in all the resistant parents and was well within the grouping of resistant category. The susceptible parent Arka Jeet had a very high mean PDI and was grouped under susceptible category. Variance in these parents was very less. This indicated the true breeding nature of parents.

In F_1 generations where one of the parents was resistant to powdery mildew, the mean PDI of all the crosses was well within the resistant category and suggested the dominant nature of resistance over susceptibility.

Mean disease incidence in F_2 generation of all the crosses was also with in the resistant category with high variance in all the crosses.

B_1 generations of all the crosses were also in the resistant category. This indicates that the resistant parent bears all the genes with decreasing effects on PDI and other strain F_1 also possesses all the gene with decreasing effect on PDI so the resulting B_1 generation expresses relatively higher level of resistance.

B_2 generations of all the crosses were either resistant (A. Jeet X IIHR 352a) or moderately resistant for powdery mildew. This suggests that one of the parental strains (P_2) bears all the genes with increasing effect on PDI in low magnitude and other strain F_1 possesses all genes with decreasing effects on PDI in high magnitude.

5.3.2.2 Gene actions

Additive - dominance model was disproved in our study by the significant estimates of Mathers scaling tests and joint scaling tests. It indicated the presence of digenic non-allelic interaction in the powdery mildew resistance.

Additive, dominance, additive X additive, additive X dominance and dominance x dominance gene actions were found to contribute to the inheritance of resistance to powdery mildew.

In the cross A. Jeet X IIHR 352a dominance effect was negative and high in magnitude. The additive effect was negative and significant indicating their reinforcing effect on resistance. Epistatic gene actions were also of considerable importance in this cross. Magnitude of dominance x dominance epistasis was high but positive in direction. Duplicate type of epistasis was observed.

In the cross A. Jeet XIIHR 352b X and A. Jeet XIIHR 352c additive and dominance gene effects were negative and significant. Among the epistatic gene effects additive X dominance and dominance X dominance were significant but positive. Additive X additive component was negative but non significant , duplicate type of epistasis was pronounced.

Significant negative additive gene effect followed by negative additive X additive components in the cross A.Jeet X IIHR 352a X , A. Jeet X IIHR 352b and A. Jeet X IIHR 352c associated with duplicate epistasis indicated these crosses were promising and resistance would be fixable by selection in advanced progenies and there is a possibility of transgressive segregation in advanced generations however dominance gene effects cannot be neglected.

Significant negative dominance gene effect in all the above crosses will facilitate the use of heterosis breeding but additive gene effects cannot be neglected.

A breeding procedure such as recurrent selection could be used to improve these strains as this method exploits both additive and non additive components of gene action.

Flori's and Alvarez (1991) also found a high estimates of additive and dominance effect for powdery mildew resistance in muskmelon.

In the cross A. Jeet X IIHR 190-1, additive gene action was significant and negative whereas dominance effect was non significant. Epistatic gene action was also of considerable importance. Among them additive X additive and additive X dominance components were significant. Here also duplicate episatsis was observed. This finding is in accordance with the findings of Sivakami *et al.* (1979) who found large estimates of additive gene action for powdery mildew resistance in muskmelon.

Predominance of additive gene action in this cross suggests the pedigree method of breeding for improving this strain as this method exploits the additive component of gene action to the fullest extent.

Thus the results obtained revealed that both additive and non-additive gene effects are important. Presence of a diversity of interaction in different crosses indicates more than one mechanism may be involved in the inheritance of resistance. The six generations of all the crosses revealed the involvement of more than one dominant gene in conferring resistance to powdery mildew in muskmelon.

Pershin *et al* (1988) reported the trigenic dominance of powdery mildew resistance in cucumber. Yurina (1979) and Hodossi (1980) reported the control of three recessive genes of powdery mildew resistance in cucumber.

Takada *et al.* (1975) in cucumber and Jado and Kato (1989) in muskmelon reported the digenic partial dominance for powdery mildew resistance.

In contrary to these reports, Jagger *et al.*, 1938, Cohen and Cohen (1986), Mc Creight *et al.* (1987) Kenigsbuch and Kohen (1989) and Epinat *et al.* (1993) reported the single dominant gene control of resistance to powdery mildew in muskmelon.

5.4 DISEASE DEVELOPMENTAL STUDY

Environmental factors play an important role in the disease initiation and development. Among the weather parameters, temperature, humidity and rainfall are the major deciding factors for many foliar diseases. Role of temperature, relative humidity and rainfall on the initiation and development of Alternaria leaf blight, downy mildew and powdery mildew on the susceptible variety Arka Jeet are discussed below.

5.4.1 Alternaria leaf blight.

Alternaria leaf light incidence is dependent on temperature and relative humidity. The visible symptoms of the disease were noticed 45 days after sowing. A high (maximum and minimum) temperature and relative humidity I (morning) and II (evening) favoured the initiation of leaf blight on Arka Jeet. It is in accordance with the findings of Degenhardt *et al.* (1982) in cabbage where high temperature and relative humidity initiated the Alternaria leaf blight. The slow development of disease in the early stages may be due to less inoculum present in the atmosphere and on infected debris which serve as a source of primary inoculum. Disease development was maximum in the second week of January when temperature was around 28^0 C with a minimum of 13.8^0 C coupled with high relative humidity. Correlation between maximum temperature, minimum temperature relative humidity I (morning) and II (evening) with disease development was positive but non significant. Favourable influence of high temperature and humidity on Alternaria leaf blight development was reported by Jackson (1959) in muskmelon, Khandewal and Prasad (1970), Chahal (1970) and Norton and Boyhan (1983) in cucumber.

5.4.2 Downy mildew.

Downy mildew is another disease of muskmelon favoured by high temperature and humidity. In the present study, initiation of downy mildew occurred 40 days after sowing when maximum temperature was 28.47^0 C and relative humidity I (morning) and II (evening) were high. Requirement of high relative humidity for infection with downy mildew on muskmelon was also felt by Duvdevani *et al* (1946) and Thomas (1977) in muskmelon. Low inoculum density in the atmosphere could be the reason for slow growth of disease in the initial stages. Disease development was maximum in the first week of January when temperature starts to increase and relative humidities were moderate. Correlation between maximum temperature and downy mildew development was positive but non significant whereas negative correlation was seen between minimum temperature and disease development. Relative humidity also positively correlated with downy mildew

development. When temperature is high relative humidity requirement for disease development was moderate. High temperature requirement of downy mildew of muskmelon is also reported by Bains and Jhooty (1980) from Punjab. However Maharishi and Sridharan (1988) found that a relative humidity of 75 percent was conducive for disease development in field, temperature having a secondary negative effect on infectivity of air borne sporangia. From this study it is evident that high temperature in the range of 27-28° C and moderate relative humidity favour the high incidence of downy mildew on muskmelon.

5.4.3 Powdery mildew.

Powdery mildew, in contrary to downy mildew and Alternaria leaf blight requires a cool temperatures and dry weather. In the present study disease initiation occurred in the last week of September when temperature was moderately high with relatively high relative humidities due to scanty rainfall. High relative humidity and rainfall may help for the conidial germination and penetration in to the leaf tissue. Abiko and Kishi (1979) reported the need of high humidity for conidial germination and infection of powdery mildew on muskmelon. However, disease development was faster as temperature and relative humidity were declining. Disease development was maximum when temperatures and relative humidity were minimum and rainfall was nil. This results again emphasis the need of low temperature and dry weather for powdery mildew development. Relationship between maximum temperature and disease development was positive but nonsignificant. Minimum temperature and relative humidity (morning) are negatively correlated to powdery mildew. Rainfall and relative humidity II (evening) found to play a major role in restricting the disease development as the correlation was negative and significant. It shows that a rainfree period with low humidity and cool temperature are conducive for powdery mildew development. Munger (1979) felt a cool temperature was ideal for powdery mildew of cucumber. Ploper (1981) reported the requirement of dry weather and cool temperature (20.26° C) for powdery mildew of peas. In contrary Singh (1987) stated that powdery mildew of cucumber increased as atmospheric humidity increased.

5.5 DISEASE PROGRESS STUDY OF ALTERNARIA LEAF BLIGHT, DOWNY MILDEW AND POWDERY MILDEW ON RESISTANT AND SUSCEPTIBLE PARENTS.

Disease progress was very slow in resistant parents (IIHR 352a and IIHR 190-1) for all the three diseases, though infection took place in the same time. Initial intensity itself was very high in the susceptible variety Arka Jeet compared to resistant lines. It could be attributed to the ability of the resistant lines to resist the infection and establishment of the pathogen.

After infection, disease progress was rapid and PDI was very high for all the diseases in the susceptible variety Arka Jeet, in contrary to this a slow and low growth was observed in the resistant lines. In the final observation also the resistant lines had PDI which was well within the ratings of resistant groups. After infection, pathogen may induce the changes in composition of leaves such as sugar content, for which susceptible variety Arka Jeet might have responded positively which resulted in the faster growth of the disease. On the other hand slow growth of disease on the resistant lines could be attributed to the negative response of these lines to the pathogens by the way of increased production of phenols which is known to hinder the growth of the pathogen. Our biochemical studies supported this type of responses.

5.6 SPORULATION STUDY

Infection and further development of pathogen on the host plant varies from susceptible to resistant plants. Susceptible plants are reported to provide congenial atmosphere and nutrients for rapid growth and development of pathogen while resistant plants try to suppress the growth of the pathogen. In our study, susceptible parent Arka Jeet recorded significantly higher concentrations of zoospores (downy mildew) and conidia (Alternaria leaf blight and powdery mildew). This could be attributed to the ability of susceptible variety to provide required nutrients especially sugars for the growth of the pathogens and may also be due to the presence of

lower contents of phenols which inhibits the growth and sporulation. On the other hand resistant lines had a significantly lower spore concentrations which may be due to the inhibition mechanism of resistant parents by producing high quantity of phenols. Phenols are known to inhibit the growth and spread of pathogen within the plant system. Heavy sporulation of *Pseudoperanospora cubensis* on susceptible varieties was reported by Cohen *et al.* (1989) in muskmelon, and Thomas (1970) in watermelon. Ratushina *et al.* (1981) found a negative correlation between sporulation intensity on leaves and host plant resistance to downy mildew in hop.

5.7 BIOCHEMICAL ANALYSIS

Resistance to disease depends on complex interaction between host and pathogen, which varies from a particular disease and crop. Several chemical substances are thought to be associated with resistance in plants (Rao, 1968). Thus total sugars, reducing sugars, non-reducing sugars, starch and total phenols of resistant and susceptible parents with their hybrids were analysed quantitatively.

5.7.1 Total sugars.

Total sugar content of the resistant and susceptible parents varied significantly before and after infection. Before infection, total sugar content of leaves of resistant parents was higher than that of susceptible parent. This could be due to the genetic makeup of the parents. After infection, total sugar content increased in all the parents. This increase in accumulation of sugars in the infected leaves seems to be due to reduced permeability of synthesising cells to sugars and due to phloem necrosis which might prevented translocation of sugars from leaves to other parts of plants. Singh and Singh (1990) also observed an increase in total sugars of chilli leaves infected with cucumber mosaic virus. The magnitude of increase in total sugar in our study was maximum in susceptible variety Arka Jeet (86.75%) which could be due to the maximum necrosis of phloem tissue due to heavy infestation. Correlation between total sugar content and disease incidence was positive but not significant.

In our study resistant parents had higher total sugars before infection which

is in accordance with Armugam and Muthukrishnan (1982) who found a high sugars in resistant parents of bhendi yellow vein mosaic than that of susceptible ones. The magnitude of increase in total sugar was high in susceptible variety than in the resistant parents.

5.7.2 Reducing sugars.

Reducing sugar content of the plant plays an important role in the infection and establishment of the pathogen. Reducing sugar content before infection did not differed significantly among resistant and susceptible parents. After infection, reducing sugar content in resistant parents decreased whereas in susceptible parent Arka Jeet increased sharply. Reduction in the reducing sugars content in the resistant parents could be due to the reduction in the photosynthesis and what ever sugurs produced are easily translocated to other parts due to lower phloem necrosis. However in the susceptible parent phloem necrosis was maximum and all the synthesised sugurs accumilated in the leaf itself leading to an increas in reducing sugur content after infection. Correlation between total sugar content and disease incidence was positive with very low "r" value (0.13) and statistically non significant. Singh and Singh (1990) found a high reducing sugar content in CMV susceptible chilli variety Pusa Jwala. Abusaleha *et al.* (1989) also found a high levels of reducing sugar in pea leaves when infected with rust disease.

5.7.3 Non-reducing sugars.

Non reducing sugar contents before infection was significantly higher in resistant parents IIHR 352c and IIHR 352a than that of susceptible parent Arka Jeet. After infection reducing sugar content increased in all the parents. The phloem nacrosis which prevented the translocation of sugurs from leaves to other parts could be the reason for increas in non reducing sugurs content in both resistant and susceptible parents after infection. Similar results were obtained by Singh and Singh (1990) who found an increase in non-reducing sugars in CMV resistant chilli variety Punjab Lal. In contrary to this Sati and Grewal (1982) found a reduction in non reducing sugars in the susceptible variety of peas when infected with Ascochyta

rabilie. Correlation study indicated a negative correlation between disease development and non-reducing sugar content of plants.

5.7.4 Starch content:

It was evident from our study that starch content showed no significant differences among parents and hybrids before and after infection which indicating starch content not involved in offering resistance to downy mildew in present study on muskmelon. However starch content of resistant parents was higher than that of susceptible parent Arka Jeet both before and after infection. Sharma *et al* (1981) observed an increase in starch content after infection with *Sphaerotheca fuliginea* in muskmelon variety Hara Madhu. Correlation study also indicated a negative relation between downy mildew incidence and starch content but the relation was non significant (r = -0.5592).

5.7.5 Total phenol content.

Phenolic compounds have been reported to be associated with the defence mechanism in various plants because of their general toxic effects (Rohringer and Sambasski, 1967). It is clear from our study, the phenols do play an important role in defence mechanism against downy mildew in muskmelon. Before infection, total phenol content was significantly higher in the resistant parents compared to susceptible variety Arka Jeet. After infection total phenols content increased in all the parents. The magnitude of increase in resistant parents was much higher than that of susceptible parent Arka Jeet where the increase was only marginal (7.35%). Our results are in accordance with the results of Lhind *et al.* (1977) in bhendi, Helal *et al.* (1978) in cucumber, Jindal et al (1979) in muskmelon. The correlation between phenol's content and downy mildew incidence was negative and highly significant. In contrary to this Narain and Mahapatra (1973) found a positive correlation between phenol content and anthracnose incidence in Chilli. In many other studies phenolic content of plants decreased after infection with diseases. Sharma *et al.* (1983) found

a decrease in phenol content of pea leaves after infection with powdery mildew diseases. Whereas Cheema (1982) found no relationship between phenolic content and resistance to anthracnose in Chilli. From our study, high phenolic content after infection could be attributed for resistance to downy mildew in muskmelon.

From all these bio-chemical study it is evident that sugar content changes in the resistant and susceptible parent after infection. Changes in sugar content in susceptible parent may favour the growth of the pathogen. However the correlation between the sugar contents and disease resistance was non-significant.

Role of phenols in disease resistance is well supported in the present study. Increase in phenol content after infection was tremendous in case of resistant parents, whereas only marginal in susceptible parent. This was further supported by the significant and negative correlation between phenol and disease intensity. So breeder should try to develop lines/varieties with high phenol contents.

Future line of work

1. In the present study, even though all the F1 hybrids are resistant to Alternaria leaf blight, downy mildew and powdery mildew, none of the F1 hybrids had horticulturally acceptable quality. So at this stage heterosis breeding may not be practicable. The immediate need is to improve the horticultural qualities of the resistant parents through population improvement approach.

2. The study revealed that genes for resistance to Alternaria leaf blight, downy mildew and powdery mildew located in the local collection. Therefore extensive survey and exploitation of native types should be conducted and documented for use in the disease resistance breeding program.

3. Additive components of resistance to Alternaria leaf blight, downy mildew and powdery mildew have to be intensified by selection to exploit inbred vigour.

4. Biochemical role of lignin and calose in imparting resistance can be studied.

SUMMARY

SUMMARY

The studies on genetics of resistance to Alternaria leaf blight, downy mildew and powdery mildew in muskmelon was taken up at the Division of Vegetable Crops, Indian Institute of Horticultural Research, Hessaraghatta, Bangalore. The objectives of the present investigations were to study the genetics of resistance to Alternaria leaf blight, downy mildew and powdery mildew, disease developmental study and correlation with weather parameters and biochemical analysis of sugars, starch and phenols and their correlation with disease resistance. The salient findings of the present investigation are summerized below.

1) Wide range of variability was observed for PDI of Alternaria leaf blight, downy mildew and powdery mildew. The phenotypic coefficient of variation was higher than genotypic coefficient of variation. The difference between PCV and GCV values was narrow indicating that resistance to these diseases was less influenced by the genotype X environment interaction.

2. High heritability (Broad sense) along with moderate to high genetic advance was observed for PDI of Alternaria leaf blight, downy mildew and powdery mildew but narrow sense heritability was lower than the broad sense heritability. This indicated that PDI of these disease was under the preview of both additive and non-additive gene action.

3. The six generation mean analysis involving parents F_1, F_2, and backcrosses, indicated that resistance to Alternaria leaf blight was controlled by more than one dominant genes.

Additive, dominance and epistatic gene effects were detected. Of which dominance gene effect is prominent than other effects. In the resistant line IIHR 352a, IIHR 352b and IIHR 352c complimentary type of epistasis was predominant and duplicate type was observed in IIHR 190-1.

4. Six generation mean analysis indicated that resistance to downy mildew was controlled by more than one dominant gene. Additive gene action was significant and negative in all the crosses. Among the interaction effects, additive X additive and additive X dominance were predominant. Complimentary type of epistasis was predominant.

5. Six generation mean analysis indicated that resistance to powdery mildew was also controlled by more than one dominant gene. Both additive and dominance effects were significant of which dominance was more pronounced than additive gene action. Among the interactions additive X dominance and dominance X dominance components were significant but positive in direction. Duplicate type of epistasis was more pronounced.

6. High temperature and humidity favoured the initiation and development of Alternaria leaf blight and downy mildew on susceptible parent Arka Jeet. However correlation between disease development and weather parameters was non significant.

7. Maximum powdery mildew development occurred when temperature and relative humidity were relatively lower. A significant negative correlation was observed between powdery mildew development and relative humidity (evening) and rainfall.

8. Fungal spore concentrations (conidia of Alternaria, zoospores of downy mildew, and conidia of powdery mildew) were 60-70 per cent higher in susceptible variety Arka Jeet than the resistant parents.

9. Total sugar content of resistant and susceptible parents increased after infection with downy mildew. The magnitude of increase was significantly higher in susceptible parent Arka Jeet than the resistant lines.

10. Reducing sugar content after infection was reduced in all the resistant parents but in susceptible parent Arka Jeet it increased.

11. Non reducing sugar content increased in all the parents after infection. The magnitude of increase was significantly higher in the susceptible parent Arka Jeet than in the resistant parents.

12. Starch content of resistant and susceptible parents did not differ significantly before and after infection. However resistant parents had a higher starch content after infection compared to susceptible parent Arka Jeet.

13. Total .phenols varied significantly among resistant and susceptible parents before and after infection. In all resistant parents, phenol's content increased sharply but in the susceptible parent increase was only marginal. IIHR 190-1 showed highest increase in total phenol after infection.

14. Correlation between total sugar content and downy mildew development and reducing sugar and downy mildew development were positive but non significant. A negative but non-significant correlation was observed between downy mildew development and non reducing sugars and starch.

15. Correlation between downy mildew development and total phenols was negative and highly significant.

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* Originals not seen