

**MANAGEMENT OF LATE BLIGHT OF POTATO**

**THESIS**

BY

**DIG VIJAY**

Submitted to



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**PALAMPUR-176 062 (H. P.) INDIA**

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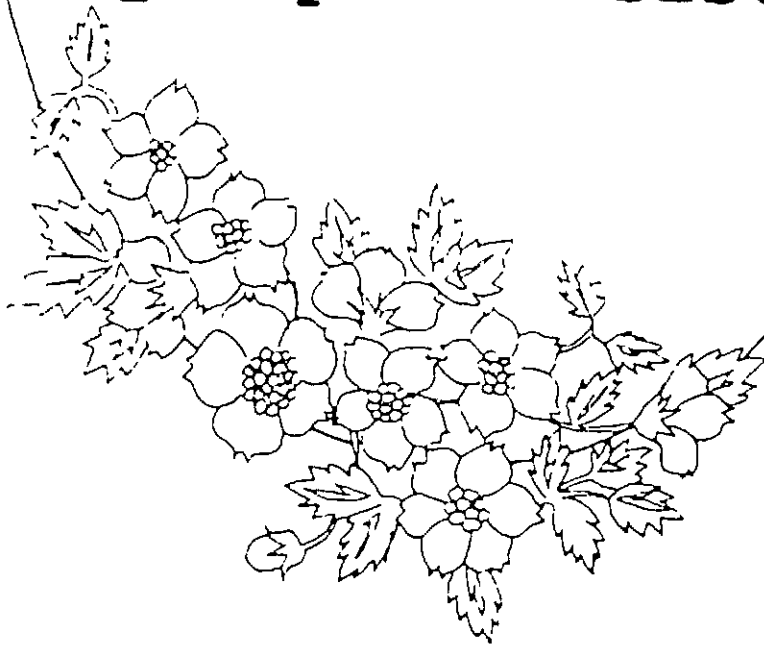
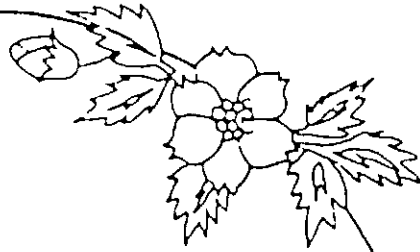
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Dedicated to  
everlasting memories  
of  
**my departed sister**



Dr. Dhanbir Singh  
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## CERTIFICATE I

This is to certify that the thesis entitled "**Management of late blight of potato**", submitted for the degree of MASTER OF SCIENCE (AGRICULTURE) in the subject of Plant Pathology of Himachal Pradesh Krishi Vishwavidyalaya, Palampur, is a record of bonafide research work carried out by Sh. Dig Vijay son of Sh. Giana Nand Sharma under my guidance and supervision and that no part of this thesis has been submitted for any other degree.

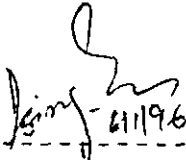
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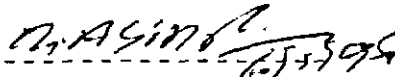
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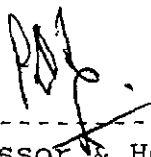
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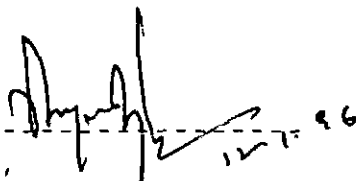
  
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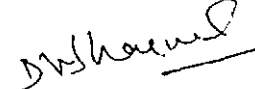
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Palampur  
Dated: November 1, 1995

  
(DIG VIJAY)

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# INTRODUCTION

## Chapter 1

### INTRODUCTION

Potato (Solanum tuberosum L.) is one of the four major crops of the world, the other three being rice, wheat and maize. It is one of the world's most nutritious sources of food for human consumption. Potato is cultivated in almost all parts of India but the major potato growing states are Uttar Pradesh, West Bengal and Bihar. Its cultivation has made big strides forward in the past four decades. Potato ranks 24<sup>th</sup> in area (0.97 million ha) and 4<sup>th</sup> in production (15.7 million tonnes) after sugarcane, rice and wheat (Shekhawat et al., 1994). India being fifth on the world map in potato production has vast scope to produce more food by improving the standard of cultivation practices and producing healthy and disease free seed tubers.

Potato is a major cash crop of Himachal Pradesh, grown on 15,855 ha of land with annual production of 1,05,858 tonnes (Anonymous, 1994). It is cultivated almost in every district of Himachal Pradesh as summer, spring and autumn crops. It is cultivated as a main crop during summer under long day conditions and high precipitation during tuber bulking stage. This crop is grown between elevations of 1500 and 2700 meters above m.s.l. in Shimla, Kangra, Kullu, Chamba and Mandi districts along rivers and rivulets and in cold deserts of Lahual and Spiti and Kinnaur at an elevation of 3000 meters and above. This constitutes about 88 per cent

of total potato growing area of the state. Spring crop is taken during January - May in Kangra and some parts of Sirmour and Shimla. This crop constitutes about 6 per cent of the potato growing area. An autumn crop is taken during September - December month in low lying areas of Mandi, Kullu and Sirmour constituting the remaining 6 per cent area.

Potato is attacked by a number of fungal, bacterial and viral pathogens but the late blight disease of potato caused by Phytophthora infestans (Mont.) de Bary, is considered to be one of the most important organisms associated with the crop the world over. In India, it came almost with the crop as such. Commercial cultivation of potato in India was initiated around 1928 in a modest manner in the north and south Indian hills, which have climatological similarity with the European temperate conditions.

The active growth period of the summer crop in Himachal Pradesh, coincides with the advent of monsoon rains, and prevalence of low temperature, high humidity, frequent rains and high precipitation during the crop season, is congenial not only for luxuriant crop growth but also favours the development of late blight caused by Phytophthora infestans. Similarly, in spring crop, low temperature and rains have become a serious threat to potato cultivation with the breakdown of resistance in commercially cultivated cultivar 'Kufri-Jyoti'. Disease incidence and severity have been greatly increased since 1986 in all

potato growing areas, especially during summer, in hills, causing severe reduction in yield and quality (Dutt, 1982). Seed tubers have been adversely affected due to infection.

The racial pattern was simple till 1966 (only 0; 1 and 4 races). With the adoption of cultivars having R-genes resistance after 1966, new and complex races have started appearing. So far, 82 races have been observed in our country, though all the races do not appear during the same season and all at one point (Dutt, 1982).

Therefore, it is not desirable to breed new cultivars with R-gene resistance. For this purpose, it is necessary to develop an effective fungicide spray schedule of protectant and systemic fungicides and to integrate host resistance with protective fungicide sprays for the effective and economic management of the disease.

It was therefore proposed to undertake this problem with the following objectives:

1. To evaluate protectant and systemic fungicides against Phytophthora infestans.
2. To eradicate late blight tuber infection by systemic fungicides.
3. Screening of potato hybrids/varieties under laboratory and field conditions.
4. To formulate economic spray schedule of protectants and systemic fungicides for the control of the disease.
5. To integrate the effect of host resistance with fungicide sprays.



**REVIEW  
OF  
LITERATURE**

## Chapter 2

### REVIEW OF LITERATURE

Late blight of potato is a destructive disease especially in high rainfall areas of H.P. Literature pertaining to different management aspects of this disease has been reviewed under the following headings:

- 2.1 Protectant and systemic fungicides
- 2.2 Host resistance
- 2.3 Spray schedules
- 2.4 Integrated management.

#### **2.1 Protectant and systemic fungicides:**

Many fungicides have been reported effective against Phytophthora infestans (Schwin and Morgot, 1991; Tkachenko, 1991). However most of the recommended fungicides often fail to provide adequate control, if not applied at appropriate time. Bruck et al. (1980) obtained 50 per cent mycelial inhibition of P. infestans in vitro with metalaxyl (ED<sub>50</sub> 0.1-0.5 ppm), however, sporulation of the fungus was inhibited at lower concentrations. They further reported that metalaxyl had little or no effect on sporangium or zoospore germination. Bock (1981) recommended sprays of fentin hydroxide @250-350 g/ha and fentin acetate @160-260 g/ha against foliar and tuber blight of potato caused by P. infestans. To reduce the phytotoxicity of organotin compounds, he suggested the use of admixtures of organotin fungicides with maneb and mancozeb. Bruck et al. (1981)

reported effectiveness of chlorothalonil and mancozeb in inhibiting spore germination, lesion expansion and sporulation. Dutt (1982) has reviewed the work for fungicidal management of late blight in plains and Shimla hills. Metalaxyl sprays @0.8 kg or 1 kg/ha have been found highly effective both for decreasing the disease incidence and increasing the yield (Bhattacharyya et al., 1983). Lopatin et al. (1984) reported excellent control of late blight in field trails with Ridomil MZ. Khanna and Sharma (1981) reported the effectiveness of Ridomil MZ against late blight of potato in plains. De and Sengupta (1988) observed lowest disease incidence and highest tuber yield and profit with mancozeb sprays @2kg/ha in plains of India. Similarly Rao and Veeresh (1989) reported control of potato blight with sprays of mancozeb on susceptible cultivar Kufri Chandramukhi in plains of South India. Thind et al. (1989) evaluated six fungicides against P. infestans by detached leaf technique and found that pre inoculation sprays of Dithane M-45, Foltaf, Mikal and Ridomil MZ and post inoculation sprays of metalaxyl and metalaxyl + mancozeb were effective in controlling the disease. Alam et al. (1991) reported control of potato blight with Ridomil MZ and Dithane M-45. Cohen (1986b) achieved good control of late blight with propamocarb sprayed at 10 day intervals. Propamocarb (Previcur N) gave 90 per cent control of late blight epidemics in Isreal, however, its performance was not good under laboratory conditions and had a little curative

efficacy (Samoucha and Cohen, 1990). Lochel and Birchmore (1990) studied the effect of propamocarb on the development of P. infestans in potato crop and found a linear increase in control of disease as the time interval between propamocarb application increased. Bhattacharyya et al. (1987) showed acropetal translocation of oxadixyl both in the top and bottom leaves of potato and reported its effectiveness upto 32 days. Cook and Little (1992) reported effectiveness of oxadixyl for the control of P. infestans upto 14 days after treatment. Jones et al. (1990) reported excellent performance of dimethomorph, a cinamic acid derivative, as protectant and curative fungicide against P. infestans on potatoes and tomatoes. Selective activity of dimethomorph on Oomycetes, including P. infestans infecting potatoes, was demonstrated by Tomat (1992). All stages in the growth cycle of P. infestans were inhibited at low concentrations of dimethomorph (0.2-1.6 ug/ml).

Repeated use of systemic fungicides against a disease especially a polycyclic disease leads to the development of resistant strains in pathogen (Kadish and Cohen, 1981). Cohen and Reuveni (1983) reported appearance of resistance to metalaxyl in P. infestans. Since then, the proportion of field isolate resistant to fungicides has remained consistently high (Cohen and Grinberger, 1987). On the other hand a variety of protectant fungicides provide only partial control of the disease. Josepovits and Dobrovalszky (1985) suggested the use of mixture of fungicides with different

modes of action is the best strategy to check the build up of resistance. Mantecon and Escande (1984, 1985) have achieved best control of disease with a combination of metalaxyl + mancozeb and ofurace + mancozeb sprayed at fortnightly and weekly intervals respectively. Platt (1985) reported better control of potato blight with sprays of metalaxyl + mancozeb at 14 day intervals than with metalaxyl alone under moderate to severe disease pressure in Canada. However, metalaxyl + mancozeb was not effective under high disease pressure in pot experiments. Samoucha and Cohen (1986) reported that fungicides with different modes of action exhibit increased efficacy in the control of late blight. Ridomil Zineb (metalaxyl + zineb) gave better disease control and crop yields in comparison to other fungicides (Stachewicz et al., 1987). Bhattacharyya et al. (1987) have reported two formulations of oxadixyl (oxadixyl + mancozeb and oxadixyl + copper oxychloride) and chlorothalonil hold promise in controlling foliage blight but failed to prevent tuber infection. Samoucha and Cohen (1988) recommended cymoxanil mixtures with either mancozeb (as Mancur) or with mancozeb and oxadixyl (as Pulsan or Sandocur-M) for control of metalaxyl resistant P. infestans populations in Israel. Somoucha and Cohen (1989) reported mixture of mancozeb and cymoxanil (Mancur) highly effective and synergistic in controlling phenylamide resistant isolate of late blight fungus. Tyuterev and Tkachenko (1990) reported the use of Ridomil MZ 25% (metalaxyl), tank

mixtures of various fungicides, Arcerid (metalaxyl + metiram) and others to control P. infestans in Russia. Dowley (1991) has monitored the results of application of phenylamide based fungicides over a period of six years in Irish Republic. He observed that mancozeb alone delayed the onset of blight by 10 days, whereas fungicides mixtures delayed the onset on disease by 10-22 days. Systemic and contact fungicides mixture reduced the level of foliage blight and resulted in increase in tuber yield. Dowley (1992) has suggested combined use of systemic and contact fungicides for the management of potato blight. Though metalaxyl + mancozeb mixture delayed the disease progress more effectively than mancozeb alone, but failed to give significant control of tuber infection (Bradshaw, 1992). Canteri et al. (1993) have reported that mixture of dimethomorph + chlorothalonil was more effective than dimethomorph + mancozeb under high disease pressure.

Infection of potato tubers by P. infestans occurs when sporangia produced on infected haulms are washed down with rain into potato ridges (Lapwood, 1977). This is a major cause of loss in yield and about 40 per cent of the yield is lost annually in Shimla hills (Dutt, 1980). Boyd (1980) conducted experiments on tuber borne infection and showed haulm infection from the tubers of cultivar King Edward. He noticed infection on basal leaves when tubers were inoculated with a complex race of P. infestans and same race was recovered from the leaves and soil near the seed tuber.

Hartill (1980) reported both spray and seed tuber treatments of metalaxyl and milfuram effective for late blight control in potatoes. The treated tubers did not develop symptoms of late blight until the flowering stage of the crop and subsequent disease progress was slow. Easton and Nagle (1984) reported foliar sprays of metalaxyl and chlorothalonil for controlling foliage and tuber blight under high rainfall conditions. Considerable amount of work has been done on factors affecting foliar infection (Fry, 1981). However, comparatively little work has been done on factors responsible for tuber infection or its control (Boyd, 1972). Arora et al. (1987) studied factors affecting loss in yield by late blight tuber infection on potato cultivar Kufri Chandramukhi and found variable amount of tuber infection under almost similar conditions of foliar infection in different years. They further reported a high degree of correlation coefficient between foliar and tuber infection. Factors such as rainfall coinciding with different amount of sporulation of the pathogen in foliage were responsible for variable infection of potato tubers in soil. Arora (1989) observed large number of small tubers infected with blight and concluded that immature tubers showed more susceptibility to infection as compared to mature tubers. Singh and Bhattacharyya (1990) reported that tuber treatment with oxadixyl and metalaxyl for 30 minutes was not effective in eradicating late blight infection. However, sprouted seed tubers treated with metalaxyl gave excellent control of

blight.

### **2.1 Host resistance:**

Management of late blight through host resistance is the most effective method. Germplasm evaluation is the most important aspect for the reliability and success of a resistant variety. Simmonds and Wastie (1987) reported methods of handling data from field trials and found that resistance expressed in small plot field trials is the base with which data from other types of test are compared, but field trials are subject to variation caused by the environment, the pathotype employed and the way in which data are collected and analysed.

In India, the work on breeding resistant varieties has made progress in recent years (Sharma et al., 1983; Bhattacharyya et al., 1986). Arora et al. (1986) screened sixteen cultivars in Shimla hills with regard to their time of disease appearance, duration of epidemic stages and mean rate of infection in different blight epidemics, occurring naturally in field and laboratory tests. Singh et al. (1988) have studied the histopathology of resistant and susceptible cultivar electronmicroscopically and found that penetration and colonization of fungus was delayed in resistant varieties. Singh and Bhattacharyya (1987) reported that field resistance was more in Kufri Jyoti than Kufri Badshah, however area under disease progress curve (AUDPC) was lower in Kufri Badshah. Prasad and Nagaich (1983) identified three potato hybrids SLB/H-40, SLB/M-45 and SLB/O-255 resistant to

P. infestans under laboratory conditions. Arora et al. (1985) screened sixteen cultivars on the basis of foliar and tuber infection by P. infestans in field under natural conditions at CPRI Shimla and found that the tuber infection on varieties was not in accordance with their foliar infection. Singh et al. (1988) evaluated 337 potato genotypes for resistance to late blight under natural epiphytotic conditions in Shimla hills. Based on AUDPC values 14 genotypes were identified as resistant and 15 genotypes moderately resistant. Ram (1992) screened 49 germplasm accessions and 89 hybrid lines at Central Potato Research Station, Shillong and found that two potato hybrids (SS/C-562 and SS/E-606) and one accession line (1632) were immune to late blight. On the basis of apparent infection rate ( $r$ ), he further reported that four hybrids CP-1699, CP-1731, SS/E-908, SS/M-40 and one accession line 2709 were resistant to blight. Sharma (1994) evaluated fifteen advanced potato hybrids in Shimla hills and found that QB/A-9-120, QB/B-92-4 and EB/A-304 possessed a high degree of minor and major gene resistance to P. infestans.

Kotova (1982) reported a high degree of non-specific resistance in potato hybrids S211-15, S212-51, S218-1, S218-34 and S236-74. He further suggested that degree of resistance depended mainly on genotypes and was little affected by date of inoculation. Tegera and Fouarge (1984) reported resistance of whole tubers in greenhouse tests was similar to resistance of tubers in field tests. They further

suggested that field test was more reliable method for selecting field resistant clones in breeding programmes. Zoteeva (1987) reported that most resistant hybrids were obtained from the crosses of Solanum polytrichon, S. verrucosum and S. simplicifolium. Pika and Podgaetskii (1987) reported high degree of resistance to P. infestans both in foliage and tubers of varieties Vaki, Pallas, Pirola and the hybrids VIR73-85, Pg286, O121430, Pg423, 7343-18, CIP702 and 07-214-30 under field and laboratory tests in Ukraine. Klyukina (1988) evaluated 88 hybrids in the central Urals, USSR against P. infestans and found that hybrids with Solanum polytrichon (P41-20) and S. Stoloniferum (S218-34) were resistant to Phytophthora.

### 2.3 Spray schedules:

Late blight disease has been reported to be controlled by many contact and systemic fungicides but most of the fungicides reported effective against P. infestans are very costly and have a specific mode of action. Therefore, it is necessary to evolve an economic spray schedule of protectant and systemic fungicides. Misra et al. (1987) reported that late blight of potato was effectively controlled by giving three sprays of mancozeb @0.2% at an interval of 15 days in plains and four sprays of same fungicide at an interval of 10 days starting from the first appearance of blight in mid-hills of Orissa. Viswanathappa et al. (1988) reported management of late blight disease in rainfed areas by giving five sprays of mancozeb @0.25% at 15 day intervals. Raj

Kumar et al. (1990) reported early and late blight control with thiophanate-methyl @1%, carbendazim @0.1%, mancozeb @0.2% or bitertanol @0.1% fungicides sprayed thrice at an interval of 20 days. De and Sengupta (1991) obtained economic control of potato late blight by three sprays of Deconil 2787 (chlorothalonil) @1.5 kg/ha at 10 day intervals starting from the first appearance of disease under natural infection by P. infestans. De and Mohasin (1993) reported good control of P. infestans with three sprays of mancozeb @0.2% at an interval of 10 days and recorded significant increase in yield and highest cost-benefit ratio in plains of West Bengal. Singh and Sharma (1993) reported that three sprays of Ridomil MZ @0.25% at 20 day intervals were highly effective in controlling the disease as compared to seven sprays of mancozeb at an interval of 7 days under natural epiphytotic of late blight in high hills of Himachal Pradesh. An economic sprays schedule comprising of one spray of Ridomil MZ @0.25% alternated with two sprays of Dithane M-45 has been suggested for the control of late blight disease in North-Western plains of India (Sharma, 1994). Prasad (1994) reported that one spray of oxadiaxyl + mancozeb or metalaxyl + mancozeb followed by two sprays of mancozeb were highly effective and economic during the years of an early outbreak of the disease in Patna.

Swiech (1988) reported that three sprays of metalaxyl (Ridomil plus 45WP) or two sprays of Kupromet followed by one spray of copper oxychloride were effective in controlling

the disease but 7 per cent isolates of P. infestans showed resistance to metalaxyl. Villanueva (1989) observed that spray of Ridomil MZ after 14 days of emergence followed by mancozeb or curzate-M effectively controlled the disease and fungicide treatment did not differ significantly with those sprayed first with contact fungicides followed by Ridomil MZ. However, a substantial increase in yield was noted in most of the sequential treatments as compared with the application of the standard fungicide alone. Hossain et al. (1990) reported best control of P. infestans and highest yield from the plots of cultivars Multa spray thrice with Ridomil MZ @0.25% in Bangladesh. Fontem and Aighewi (1993) reported that three sprays of Ridomil plus (metalaxyl + cuprous oxide) at 15 day intervals reduced the epidemic rate and area under disease progress curve and gave significant increase in yield.

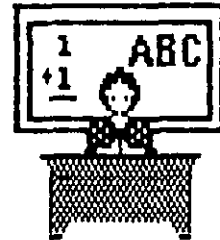
#### **2.4 Integrated management:**

The use of race specific resistance governed by one or a few host genes has been ineffective in potato-P. infestans system as a control procedure because of rapid appearance of new races of pathogen which are virulent to cultivars containing such genes. Virulent biotypes of the pathogen are detected shortly after varieties with race specific resistance are released (Thurston, 1971). In late blight, the effect of polygenic resistance is the reduction of sporulation capacity of lesions, reduction of lesion size and retardation of rate of sporangiophore growth (Gujman,

1964; Knutson, 1962; Thurston et al., 1962). Collectively these components reduce the rate of epidemic development (Vander Plank, 1967). Periodic application of protective fungicides also reduce the rate of epidemic development of polycyclic diseases. Therefore, the integration of polygenic resistance with fungicides has become the best strategy in the management of potato late blight.

Fry (1975) determined the integrated effect of polygenic resistance and a protective fungicide on the development of potato late blight and reported that both polygenic resistance and periodic application of a protective fungicide effectively reduced the apparent infection rate. He further concluded that on the basis of reduction in apparent infection rate ( $r$ ), the effect of polygenic resistance in Sebago was equivalent to 0.5 kg (a.i) mancozeb per hectare applied at weekly intervals to Russet Rural. Fry (1977) reported that the efficacy of fungicide was more when applied according to 'Blitecast' than applied after each 1.27 cm of rainfall. He concluded that less amount of fungicide was required to a cultivar with polygenic resistance according to the 'Blitecast predictions'. Fry (1978) suggested that AUDPCs were more reliable than apparent infection rate or final disease ratings for the quantification of effect of fungicides and general resistance on infection by *P. infestans* in potatoes. General resistance and fungicide application both reduced disease and the effect of each was additive. Spadafora et

al. (1984) developed simple and complex late blight forecast models and used for the efficient and economic use of spraying operations to different potato cultivars. Fry and Shtienberg (1990) used field experiments and computer simulation experiments in a complementary fashion to provide the basis for integrating the host resistance and fungicides to manage early and late blight of potato. Olofsson (1992) conducted experiments on reduced fungicide dose rates for the control of potato blight to moderately resistant potato cultivar and concluded that a dose of 1.5 - 2.0 kg/ha of mancozeb to moderately resistant potato cultivars gave adequate control. Incorporation of host resistance into a reduced sprays strategy enabled large reductions in the amount of fungicide required for adequate management of early and late blight of potato (Shtienberg et al., 1994).



# MATERIALS AND METHODS

## Chapter 3

### MATERIALS AND METHODS

#### 3.1 ISOLATION AND MAINTENANCE OF PURE CULTURE

Late blight infected leaves were collected from the potato fields and brought to laboratory for isolation of Phytophthora infestans. Small bits of 2-3 mm having well separated lesions were cut from the junction of diseased and healthy tissue with the help of a sterilized blade. The bits were surface sterilized by dipping in 0.5 per cent sodium hypochlorite (NaOCl) solution for 2-3 minutes and washed 3-4 times with sterilized distilled water. The bits were placed on a sterilized filter paper to remove excess of water and finally transferred to lima bean agar slants under aseptic conditions. The slants were incubated at  $18 \pm 2^{\circ}\text{C}$ . The culture was purified by single hyphal tip method and maintained on lima bean agar at  $5 \pm 1^{\circ}\text{C}$  in refrigerator. The stock cultures were revived after every 15 days by transferring in lima bean agar slants.

#### 3.2 SPORANGIAL PRODUCTION:

In vitro sporangia were produced in mass by tuber slices method. Thin tuber slices (1-2 mm) of susceptible variety Kufri Chandramukhi were inoculated with a bit of mycelium of P. infestans under aseptic conditions. The slices were kept in humidity chambers and incubated at  $18 \pm 2^{\circ}\text{C}$  for 10 days. Sporangia produced were utilized for laboratory and green house experiments.

### 3.3 EVALUATION OF FUNGICIDES:

Four systemic and four non systemic fungicides were evaluated in vitro to see their effect on sporangial germination of P. infestans. In all eight fungicides including, Ridomil MZ 72 WP (metalaxyl 8% + mancozeb 64%), SAN 518 F 64 WP (oxadixyl 10% + copper oxychloride 54%), Aliette 80 WP (fosetyl Al), Previcur N (propamocarb hydrochloride), Indofil M-45 75 WP (mancozeb), Blitox-50 WP (copper oxychloride), Chlorothalonil 75 WP and Difolatan 80 WP (captafol) were tested by slide germination method (Anonymous, 1943) and detached leaf technique (Thind et al., 1989).

#### 3.3.1 Effect of fungicides on sporangial germination:

Double strength suspension of systemic fungicides (250, 500, 750, 1000  $\mu\text{g ml}^{-1}$ ) and non-systemic fungicides (500, 1000, 1500, 2000  $\mu\text{g ml}^{-1}$ ) were separately prepared in sterilized distilled water. Sporangia were taken from 10 day old culture of P. infestans grown on tuber slices and suspended in sterilized distilled water. Sporangial suspension (0.5 ml) was added to 0.5 ml of fungicidal suspension (double strength) in a test tube and shaken well. A drop of this mixture was placed in cavity slide(s) and incubated at  $18 \pm 2^\circ\text{C}$  in humidity chambers created in 110 mm petri dish containing two layers of moist filter paper. Three replications were kept under each treatment. Sporangial germination was counted after 72 hours of incubation. Sporangial germination in distilled water served

as control. Inhibition of sporangial germination was calculated by the formula:

$$\text{Per cent inhibition} = \frac{\text{Per cent germination in control} - \text{Per cent germination in treatment}}{\text{Per cent germination in control}} \times 100$$

### 3.3.2 Effect of fungicides on pre and post infection of late blight of potato in vitro

Effect of seven fungicides viz. Ridomil MZ (0.25% , SAN 518 (0.25%), Previcur N (0.25%), Indofil M-45 (0.25%), Blitox 50 (0.3%), Chlorothalonil (0.25%) and Bordeaux mixture (0.8%) were evaluated 24 hours before and after artificial inoculation of P. infestans by detached leaf technique.

Forty five days old leaves of cultivar Kufri Chandramukhi were thoroughly washed with tap water, air dried and placed in 110 mm plastic petri plates lined with moist cotton pad. Three leaves were kept in each petri plate with their abaxial surfaces touching the cotton pads. The leaves were inoculated with sporangial suspension ( $4.5 \times 10^4$  sporangia/ml) with the help of an atomizer. The test fungicides were sprayed 24 hours before and after artificial inoculation. Each treatment was replicated five times and leaves sprayed with plain water served as control. The petri plates were incubated in growth room at  $20 \pm 2^\circ\text{C}$  and light period of 12 hours with flourescent tubes. The data on per cent leaf area infected were calculated by using graph sheets and sporulation was evaluated using a haemocytometer

### 3.3.3 Effect of fungicides on pre and post infection of late blight in pot experiments under green house conditions

All the fungicides tested by detached leaf technique were further evaluated for their efficacy in pot experiment as pre and post inoculation treatments. Plants of Kufri Chandramukhi were raised in plastic pots (10' diameter) under green house conditions. The test fungicides were sprayed on 45 days old plants with the help of pneumatic hand sprayer 24 hours before and after inoculation with sporangial suspension ( $4.5 \times 10^4$  sporangia/ml) of P. infestans. Each pot containing two plants and three pots were kept for each treatment. Check plants were sprayed with plain water. The humidity was maintained 90 per cent and temperature of green house varied 18-22°C. Data on disease severity were recorded on 1-9 scale (Estrada-Ramos et al., 1983) after 10 days of fungicide sprays and data on per cent disease control were calculated.

### 3.3.4 Effect of tuber infection on late blight development under green house conditions:

Five different levels of infection viz., 5, 10, 15, 20 and 25 per cent were created by artificial inoculation of tubers of Kufri Chandramukhi with P. infestans. Five tubers were kept for each infection level and planted in plastic pots (6" diameter). The pots were covered with polythene sheets to maintain high relative humidity (>90%) and kept in growth chambers at  $20 \pm 2^\circ\text{C}$ . Data on per cent germination and late blight infection development were recorded

### **3.3.5 Effect of fungicides on lesion development of late blight in tubers under laboratory conditions:**

In order to see the effect of fungicides on lesion development of late blight in tubers, an experiment was laid out by using three systemic fungicides viz., Ridomil MZ, SAN518 and Aliette at two different concentrations (0.1, 0.2%) alongwith one non-systemic fungicide Indofil M-45 (0.25%). Tubers of susceptible cultivar Kufri Chandramukhi were artificially inoculated with P. infestans and incubated at  $18\pm 2^{\circ}\text{C}$  for 20 days when 20 per cent surface area of tubers were covered with late blight. Diseased tubers were treated with fungicide by dipping in fungicidal suspension for 30 and 60 minutes and dried in shade. Five tubers were kept for each treatment. Tubers were incubated at  $18\pm 2^{\circ}\text{C}$  and data on increase in lesion area were recorded 14 and 28 days after treatment. Tubers dipped in plain water served as control.

### **3.3.6 Effect of fungicides on sprout infection:**

All the fungicides tested for checking the lesion development of late blight in tubers were further screened to see their effect on sprout infection under laboratory conditions. Tubers of Kufri Chandramukhi carrying 20% surface area infection were dipped in fungicidal suspension (0.2%) for 30 minutes. In case of Indofil M-45, the concentration used was 0.25%. Five tubers were used for each treatment and tubers given plain water dip served as

18±2°C for 28 days. Observations on sprout infection were recorded after 4, 8, 12, 16, 20, 24 and 28 days of treatment. The experiment was repeated twice.

### **3.4 EVALUATION OF HOST RESISTANCE**

#### **3.4.1 In vitro screening of potato hybrids/varieties:**

Seventeen potato hybrids/varieties viz., JI-1857, QB/A-9-120, PH/F-1545, MS/79-34, PJ-376, JI-5857, MS/78-46, JH-222, QB/B-92-4, MS/79-10, EB/A-304, HB-82-36, HB-83-185, HB-82-372, HB-83-39 alongwith checks Kufri Jyoti and Kufri Chandramukhi were screened for their resistance to late blight under laboratory conditions by detached leaf technique. Five leaves of one month old plant of each variety/hybrid were inoculated with 10 days old culture of P. infestans ( $4.5 \times 10^4$  sporangia/ml) grown on potato slices. Petri plates containing detached leaves were incubated at 20±2°C with 12 hours light with flourescent tubes in growth chamber. Observations of blight infection, incubation period, latent period, lesion size and spore density were recorded. The experiment was repeated thrice.

#### **3.4.2 Screening of potato hybrids/varieties in pot**

##### **experiment under green house conditions:**

All the hybrids/varieties tested in vitro were further evaluated in pot experiment under green house conditions. Five pots (10" diameter) of each potato hybrid/variety containing two plants each (45 days old) were artificially inoculated with 10 days old sporangial suspension of

than 80 per cent was maintained by spraying of water after every two hours in a day. The average temperature of green house ranged between 20-25°C. The pots sprayed with plain water served as control. Late blight intensity was scored on 1-9 scale after 10 and 15 days of inoculations.

### **3.4.3 Screening of potato hybrids/varieties under field conditions:**

Seventeen potato hybrids/varieties viz., JI-1857, QB/A-9-120, PH/F-1545, MS/79-34, PJ-376, JI-5857, MS/78-46, JH-222, QB/B-92-4, MS/79-10, EB/A-304, HB-82-36, HB-83-185, HB-82-372, HB-83-39, Kufri Jyoti and Kufri Chandramukhi were screened for their resistance to P. infestans under natural epiphytotic of late blight at Potato Development Station, Phuladhar (Mandi) in summer crop. The hybrids/varieties were planted in a randomized block design during the third week of April, 1994 (20-4-1995). The plot size was kept 2.4 x 2.0 m<sup>2</sup> with 60 x 20 cm spacing. Each treatment was replicated three times. All the recommended package of practices were followed for raising the crop. Assessment of blight on different hybrids/varieties was done at weekly intervals after the first appearance of the disease as per BMS key (Anonymous, 1947). Data on tuber yield was recorded at harvest.

All the above potato hybrids/varieties were further screened in spring crop during 1995 at farmer's field near Rice Research Station, Malan. Observations on reactions of

intervals. Data on yield was recorded at harvest .

### **3.5 FUNGICIDAL SPRAY SCHEDULES FOR ECONOMIC MANAGEMENT OF LATE BLIGHT OF POTATO**

Field trials with Kufri Chandramukhi were laid out at Potato Development Station, Phuladhar during 1994 summer crop season and spring crop during 1995 at farmer's field near Rice Research Station, Malan to see the relative performance of eight fungicidal spray schedule treatments along with control (unsprayed plots) for the economic management of late blight of potato. Each treatment was replicated thrice in a randomized block design with plot size of 3.0x2.4 m<sup>2</sup>. All the recommended package of practices were followed for raising the crop. The sprays were given before the normal appearance of late blight of potato (last week of June in summer crop and last week of March in spring crop) with Maruti foot sprayer. The spray schedule treatments used were as follows:

- i) Three sprays of Blitox-50 @0.3% and two sprays of Ridomil MZ @0.25% in the sequence of P, S, P, S, P (P=protectant; S=systemic).
- ii) Four sprays of Indofil M-45 @0.25% and one spray of Ridomil MZ @0.25% (P, P, S, P, P).
- iii) Two sprays of Ridomil MZ @0.25% and three sprays of Indofil M-45 @0.25% (S, P, S, P, P).
- iv) One spray of SAN518 @0.25% and four sprays of Difolatan @0.25% (S, P, P, P, P).

Ridomil MZ @0.25% (P, S, P, P, P).

- vi) Five sprays of Previcur N @0.25%.
- vii) Five sprays of Indofil M-45 @0.25%.
- viii) Five sprays of Previcur N + Indofil M-45 @0.18 + 0.16%.
- ix) Check (unsprayed plots).

Systemic fungicides Ridomil MZ, SAN518 and Previcur N were sprayed at 15 day intervals where as protectant fungicides were sprayed at 7 day intervals. Blight was recorded on foliage at weekly intervals as per BMS key. Terminal disease severity was computed at the end of the season and apparent infection rate (r) and area under disease progress curve (AUDPC) were calculated. Tuber yield was recorded at harvest and economics of the different spray schedules were worked out on hectare basis.

### **3.6 INTEGRATED MANAGEMENT**

#### **3.6.1 Effect of tuber treatment and sprays of fungicides on late blight development under field conditions:**

An experiment was conducted to see the effect of tuber treatment and fungicidal sprays on the development of late blight of potato at Potato Development Station, Phuladhar. Apparently diseased tubers of Kufri Chandramukhi were dipped in 0.20% suspension of Ridomil MZ for 30 minutes and dried in shade. The treated tubers were planted during the third week of April (20-4-1994) in 2.4x 2.0 m<sup>2</sup> plot with a spacing of 60x20 cm in a randomized block design. All the

the crop. Tubers dipped in plain water served as control. In all eight treatments included were as follows:

1. Tuber treatment + one spray of Indofil M-45 @0.25%.
2. Tuber treatment + one spray of Ridomil MZ @0.25%.
3. Tuber treatment + two sprays of Indofil M-45 @0.25%.
4. Tuber treatment + three sprays of Indofil M-45 @0.25%.
5. Tuber treatment + one spray of Indofil M-45 @0.25% + one spray of Ridomil MZ @0.25%.
6. Tuber treatment + five sprays of Indofil M-45.
7. Tuber treatment only.
8. Untreated + plain water spray.

Sprays were given with the first appearance of disease and each treatment was replicated thrice. Sprays of Ridomil MZ (@0.25%) were given at 15 day intervals whereas sprays of Indofil M-45 were given at 7 day intervals. The crop was regularly monitored for the appearance of disease and blight intensity was assessed at weekly intervals as per BMS key. Apparent infection rate (r) and AUDPC values were calculated. Tuber yield was recorded at harvest.

### **3.6.2 Effect of host resistance and fungicidal sprays on late blight development:**

In order to see the integrated effect of host resistance and sprays of fungicides, a field experiment was conducted during 1994 crop season at Potato Development Station, Phuladhar. The trial was laid out with three potato hybrids/varieties having different degree of resistance in a

size was kept 2.4x2.0 m<sup>2</sup> with a spacing of 60x20 cm. The detail of various treatments used were as follows:

1. QB/A-9-120 (resistant variety) + one spray of Indofil M-45 @0.25%.
2. QB/A-9-120 (resistant variety) + one spray of Ridomil MZ @0.25%.
3. QB/A-9-120 (no spray).
4. EB/A-304 (moderately resistant variety) + two sprays of Indofil M-45 @0.25%.
5. EB/A-304 + two sprays of Ridomil MZ @0.25%.
6. EB/A-304 (no spray).
7. Kufri-Jyoti (susceptible cultivar) + five sprays of Indofil M-45 @0.25%.
8. Kufri-Jyoti + three sprays of Ridomil MZ @0.25%.
9. Kufri-Jyoti (no spray).

The fungicide sprays were given before the normal appearance of late blight (last week of June). Blight intensity was assessed at weekly intervals by using BMS key. Apparent infection rate (r), AUDPC were calculated and tuber yield was recorded.

### **3.7 STATISTICAL ANALYSIS**

The data were subjected to statistical analysis where ever required. The differences among the treatments were tested for their significance by employing the Complete Randomized Block Design (Panse and Sukhatme, 1984).



# EXPERIMENTAL RESULTS

## Chapter 4

## EXPERIMENTAL RESULTS

**4.1 IN VITRO EFFICACY OF FUNGICIDES**

Eight systemic and non systemic fungicides were screened each at four concentrations against Phytophthora infestans by two different methods:

**4.1.1 Effect of fungicides on sporangial germination:**

The data obtained on per cent inhibition of sporangial germination of P. infestans (Table 4.1) revealed that all the fungicides inhibited sporangial germination at various test concentrations. In case of systemic fungicides the sporangial inhibition ranged between 20.71 to 100.00 per cent whereas in non-systemic fungicides it ranged from 18.61 to 100.00 per cent. Ridomil MZ was the most efficacious which completely inhibited sporangial germination at 750 ug ml<sup>-1</sup> of commercial product, whereas SAN516 at higher concentration (1000 ug ml<sup>-1</sup>) gave 100 per cent inhibition. With the increasing concentration all the fungicides showed deleterious effect on germination. Aliette was next best in order of their efficacy which gave 74.04 per cent inhibition at 1000 ug ml<sup>-1</sup> of concentration.

In case of non-systemic fungicides, Indofil M-45 resulted maximum inhibition of sporangial germination followed by Blitox-50 and chlorothalonil at 2000 ug m<sup>-1</sup> of concentration.

Ridomil MZ (750 ug ml<sup>-1</sup>), SAN518 (1000 ml<sup>-1</sup>) and

Table 4.1 Effect of fungicides on germination of sporangia of *Phytophthora infestans*\*

Treatment	Concentration (ug/ml)	Per cent germination	Percent inhibition
Ridomil MZ	250	22.93 (28.54)	72.09
	500	4.76 (10.24)	93.77
	750	0.00 (0.33)	100.00
	1000	0.00 (0.33)	100.00
SAN518	250	50.83 (45.47)	36.98
	500	33.19 (35.15)	60.25
	750	7.95 (13.33)	89.61
	1000	0.00 (0.33)	100.00
Aliette	250	64.70 (53.55)	20.71
	500	52.64 (46.51)	36.00
	750	38.82 (38.54)	52.62
	1000	21.36 (27.53)	74.04
Previcur N	250	63.40 (52.77)	22.38
	500	54.24 (47.43)	32.91
	750	42.39 (40.62)	47.82
	1000	23.78 (29.19)	71.02
Indofil M-45	500	57.39 (49.25)	29.43
	1000	43.16 (41.06)	47.09
	1500	14.32 (22.24)	82.32
	2000	0.00 (0.33)	100.00
Blitox-50	500	52.97 (46.54)	35.16
	1000	31.24 (34.55)	61.32
	1500	13.00 (17.54)	83.61
	2000	1.82 (4.73)	97.85
Chlorothalonil	500	65.95 (54.34)	18.61
	1000	32.10 (34.45)	60.06
	1500	14.97 (22.67)	61.70
	2000	2.60 (7.68)	96.76
Difolatan	500	57.81 (49.52)	28.94
	1000	43.21 (41.07)	46.36
	1500	36.92 (37.39)	54.39
	2000	24.18 (29.35)	70.15
Control	-	81.73 (64.98)	

\* Average of three replications. Figures in parenthesis are angular transformed values

CD (0.05) Fungicide = 4.83

Concentration = 3.42

Fungicide x Concentration = 9.67

Indofil M-45 (2000 ug ml<sup>-1</sup>) were concluded to be highly efficacious in inhibiting sporangial germination of P. infestans.

#### **4.1.2 Effect of fungicides as pre and post inoculation spray on detached leaves:**

Seven promising fungicides namely, Ridomil MZ (0.25%), SAN518 (0.25%), Previcur N (0.25%), Indofil M-45 (0.25%), Blitox-50 (0.3%), Chlorothalonil (0.25%) and Bordeaux mixture (0.8%) were evaluated for their efficacy as pre and post inoculation sprays on detached leaves of susceptible cultivar Kufri Chandramukhi. Data on per cent leaf area infected were recorded ten days after inoculation and are presented in Table 4.2.

Data indicate that all test fungicides reduce the per cent leaf area infected by P. infestans in comparison to check (unsprayed). Ridomil MZ was most efficacious both in pre and post inoculation sprays as it resulted in cent per cent healthy leaf area in comparison to 83.40 and 86.60 per cent leaf area infected respectively in checks. SAN516 (0.25%) was the next best fungicide as it resulted 4.70 and 15.30 per cent leaf area infected followed by Previcur N (0.25%) which gave 6.60 and 28.70 per cent leaf area infected as pre and post infection treatment respectively. Blitox-50 (0.3%) was least effective in controlling the disease SAN518 sprayed leaves resulted least sporulation ( $0.4 \times 10^3$  sporangia ml<sup>-1</sup>) followed by Previcur N ( $0.8 \times 10^3$  sporangia ml<sup>-1</sup>) in pre inoculation treatment. These

Table 4.2 Effect of fungicides on pre and post infection of late blight of potato  
(detached leaf technique)\*

Fungicide	Concentration (%)	Pre infection		Post infection	
		PLAI**	Sporulation (per ml)	PLAI**	Sporulation (per ml)
Ridomil MZ	0.25	0.00 (0.55)	-	0.00 (0.55)	-
SAN 518	0.25	4.70 (12.40)	0.4x10 <sup>3</sup>	15.30 (22.90)	0.6x10 <sup>3</sup>
Previcur N	0.25	6.60 (14.66)	0.8x10 <sup>3</sup>	28.70 (32.33)	0.7x10 <sup>4</sup>
Indofil M-45	0.25	8.40 (16.70)	0.2x10 <sup>4</sup>	43.60 (41.30)	3.2x10 <sup>4</sup>
Blitox-50	0.30	28.26 (32.07)	1.0x10 <sup>4</sup>	78.20 (62.26)	3.5x10 <sup>4</sup>
Chlorothalonil	0.25	23.70 (29.08)	0.8x10 <sup>4</sup>	67.80 (55.54)	2.8x10 <sup>4</sup>
Bordeaux mixture (4:4:50)	0.80	22.36 (28.11)	0.6x10 <sup>4</sup>	72.50 (58.55)	3.7x10 <sup>4</sup>
Control (inoculated)	-	83.40 (66.16)	5.2x10 <sup>4</sup>	86.60 (69.07)	4.9x10 <sup>4</sup>
Control (uninoculated)	-	0.00 (0.55)	-	0.00 (0.55)	-
CD (0.05)		3.36		4.66	

\* Average of five replications

Figures in parentheses are angular transformed values

\*\* Percent leaf area infected

-- No sporulation

fungicides were also found effective in reducing sporulation in post inoculation spray.

Pre inoculation spray was better both in reducing leaf area infected as well as sporulation than post inoculation spray.

#### **4.2 EFFICACY OF FUNGICIDES AS PRE AND POST INOCULATION**

##### **TREATMENT IN POTS UNDER GREEN HOUSE CONDITIONS**

Seven fungicides viz., Ridomil MZ (0.25%), SAN518 (0.25%), Previcur N (0.25%), Indofil M-45 (0.25%), Blitox-50 (0.3%), Chlorothalonil (0.25%) and Bordeaux mixture (0.8%) were further evaluated for their efficacy as pre and post inoculation sprays on potted plants of Kufri Chandramukhi under green house conditions. Data on disease intensity were recorded after 10 days of inoculation and per cent disease control presented in Table 4.3 indicate that sprays of Ridomil MZ (0.25%) completely checked the disease development when applied as pre inoculation treatment. However, post inoculation spray of Ridomil MZ (0.25%) resulted 96.07 per cent disease control whereas SAN518 (0.25%) gave 80.74 and 70.37 per cent disease control and Previcur N (0.25%) gave only 62.96 and 51.85 per cent disease control as pre and post inoculation sprays respectively. Blitox-50 (0.3%), Chlorothalonil (0.25%) and Bordeaux mixture (0.8%) were found to be least effective and rated at par in their efficacy when applied as pre inoculation treatments, however, post inoculation sprays of Bordeaux mixture (0.8%) and chlorothalonil (0.25%) were

**Table 4.3 Relative efficacy of fungicides in controlling pre and post infection of late blight of potato under green house conditions**

Fungicide	Concentration (%)	Per cent disease control after 10 days	
		Pre infection	Post infection
Ridomil MZ	0.25	100.00 (89.08)	96.07 (82.69)
SAN 518	0.25	80.74 (64.61)	70.37 (57.04)
Previcur N	0.25	62.96 (52.72)	51.85 (35.89)
Indofil M-45	0.25	37.03 (37.43)	22.22 (27.81)
Blitox-50	0.30	16.67 (24.09)	5.55 (8.64)
Chlorothalonil	0.25	22.22 (27.81)	16.67 (24.09)
Bordeaux mixture (4 : 4.50)	0.80	22.22 (27.81)	11.11 (16.36)
Control (inoculated)	-	0.00 (0.92)	0.00 (0.92)
Control (uninoculated)	-	100.00 (89.08)	100.00 (89.08)
CD (0.05)		9.23	14.35

\* Average of three replications

Figures in parentheses are angular transformed values

- Plain water

better than Blitox-50 (0.3%).

In general, pre inoculation sprays of fungicides were better than post inoculation sprays.

#### **4.3 DEVELOPMENT OF LATE BLIGHT IN POTS WITH DIFFERENT LEVELS OF TUBER INFECTION:**

Tubers with different levels of late blight infection (5, 10, 15, 20 and 25 per cent surface area infected) were planted in pots under green house conditions. Data on per cent germination and infection recorded (Table 4.4) reveal that tubers carrying 5 and 10 per cent infection level gave 100 per cent germination and did not show late blight development. However, tubers with 15 and 20 per cent infection level gave 90 per cent germination. Germination was adversely affected at 25 per cent level of infection and resulted 60 per cent germination. The plants raised from tubers having 15, 20 and 25 per cent level of infection showed 100 per cent disease development.

#### **4.4 Efficacy of fungicides in containing blight lesion in tuber under laboratory conditions**

Three systemic fungicides namely, Ridomil MZ, Aliette and SAN 518 at two concentrations each (0.1 and 0.2%) were evaluated alongwith one protectant fungicide Indofil M-45 (0.25%) by dipping artificially inoculated tubers in fungicidal suspensions for 30 and 60 minutes. The tubers were incubated at  $18 \pm 2^{\circ}\text{C}$  and increase in lesion area was recorded after 14 and 28 days of treatment (Table 4.5) indicate that all the test fungicides were effective in

**Table 4.4 Effect of different levels of tuber infection on late blight development under green house conditions**

Infection level in tubers (%)	Germination (%)	Late blight infection
5	100	-
10	100	-
15	90	+
20	90	+
25	60	+

\* Average of five tubers

- No infection

+ Late blight infection

5 Relative efficacy of fungicides in inhibiting lesions on tubers under laboratory conditions\*

	14						28							
	0.1		0.2		0.1		0.2		0.1		0.2			
	30	60	Mean	30	60	Mean	Grand mean	30	60	Mean	30	60	Mean	Grand mean
MZ	0.94	0.88	0.91	0.34	0.26	0.30	0.60	2.36	2.20	2.28	1.84	1.66	1.75	2.01
	1.76	1.58	1.67	1.46	1.24	1.35	1.51	4.16	3.68	3.92	3.46	3.34	3.40	3.66
	1.20	0.92	1.06	0.80	0.76	0.78	0.92	2.78	2.80	2.79	2.66	2.22	2.44	2.61
M-45**	-	-	-	2.00	1.80	1.90	1.90	-	-	-	4.22	3.90	4.06	4.06
	-	-	-	2.46	2.50	2.48	2.48	-	-	-	5.30	5.36	5.33	5.33

e of five tubers

0.05)

Fungicide

Doses

Dip time

11 M-45 was used at recommended concentration (0.25%)

arresting blight lesion development over control (untreated tubers). However, tuber treatment with Ridomil MZ @0.2% for 60 minutes was most effective in inhibiting lesion development as it gave 1.66 cm<sup>2</sup> increase in lesion area compared with 5.36 cm<sup>2</sup> in untreated tubers after 28 days of incubation. SAN 518 was the next best treatment which gave 2.22 cm<sup>2</sup> increase in tuber lesion followed by Aliette (3.34 cm<sup>2</sup>) and Indofil M-45 (3.90 cm<sup>2</sup>). These treatments differ significantly with each other in their effectiveness. All the test fungicides at 0.2% concentration were significantly better than 0.1% concentration. However, dip time of 30 and 60 minutes did not show significant difference.

#### **4.5 EFFECT OF FUNGICIDE ON SPROUT INFECTION**

Artificially inoculated tubers of Kufri Chandramukhi carrying 20 per cent surface area infected were treated by dipping in different systemic fungicidal suspensions (0.2%) alongwith recommended fungicide Indofil M-45 (0.25%) and incubated in polythene bags at 18±2°C. Observations on *sprout infection* were recorded upto 28 days and data are presented in Table 4.6.

The sprouts emerged from Ridomil MZ (0.2%) treated tubers were free from late blight infection upto 20 days. However, SAN518 (0.2%) and Aliette (0.2%) gave protection upto 16 and 12 days respectively. Indofil M-45 gave least protection and rated at par with check. All the fungicidal treatments showed severe late blight infection after 28 days of treatment.

Table 4.6 Effect of fungicides on sprout infection under laboratory conditions (polythene bags)\*

Fungicide	Concentration (%)	Late blight infection (days after treatment)*						
		4	8	12	16	20	24	28
Radomil MZ	0.20	-	-	-	-	+	++	+++
SAN 518	0.20	-	-	-	+	++	+++	+++
Alhette	0.20	-	-	+	++	+++	+++	+++
Indofil M-45	0.25	-	+	++	+++	+++	+++	+++
Control	-	-	+	++	+++	+++	+++	+++

\* Average of five tubers

- No infection

+ Mild infection

++ Moderate infection

+++ Severe infection

#### 4.6 EVALUATION OF POTATO HYBRIDS/VARIETIES

##### 4.6.1 In vitro evaluation:

Detached leaves of seventeen potato hybrids/varieties were artificially inoculated with sporangial suspension of P. infestans. Observations on incubation period, latent period, lesion size and spore density were recorded. The data presented in Table 4.7 indicate that potato hybrids QB/A-9-120 and QB/B-92-4 were highly resistant to P. Infestans as infection on these hybrids could not establish. Potato hybrid EB/A-304 also showed resistance to P. Infestans where infection developed after 8.6 days of inoculation but did not sporulate compared with Kufri Chandramukhi which gave disease development after 3.2 days of inoculation and had maximum sporulation ( $4.3 \times 10^4$  sporangia per lesion).

Potato hybrids HB-82-372, HB-83-185 and HB-82-36 were the next best in their performance as the incubation period, latent period, lesion size and spore density of these hybrids varied between 6.6 - 7.4 days, 9.0 - 10.6 days,  $1.2 \times 0.8$  -  $1.7 \times 1.2$  cm and  $0.8 \times 10^4$  -  $0.9 \times 10^4$  sporangia per lesion, respectively. In rest of the hybrids/varieties the incubation period, latent period, lesion size and spore density varied between 3.6 - 6.8 days, 6.2 - 8.8 days,  $1.1 \times 1.0$  -  $2.7 \times 2.2$  cm and  $0.6 \times 10^4$  -  $3.7 \times 10^4$  sporangia/lesion, respectively.

##### 4.6.2 Evaluation under green house conditions:

Seventeen potato hybrids/varieties were also evaluated

Table 4.7 Evaluation of potato hybrids/varieties to *Phytophthora infestans* under laboratory conditions (detached leaf technique)\*

Potato hybrid/variety	Infection	Incubation period (days)	Latent period (days)	Lesion size (cm)	Spore density (per lesion)
JT-1857	+	4.40	6.8	2.3 x 1.4	1.0 x 10 <sup>4</sup>
QB/A-9-120	-	-	-	-	-
PH/F-1545	+	4.60	7.8	2.6 x 2.4	0.6 x 10 <sup>4</sup>
MS/79-34	+	5.20	7.6	1.1 x 1.0	1.4 x 10 <sup>4</sup>
PJ-376	+	4.80	7.2	2.3 x 1.5	1.1 x 10 <sup>4</sup>
JI-5857	+	5.00	7.6	1.7 x 1.0	2.5 x 10 <sup>4</sup>
MS/78-46	+	4.60	7.2	2.1 x 1.8	2.6 x 10 <sup>4</sup>
JH-222	+	3.60	6.0	2.7 x 2.2	3.7 x 10 <sup>4</sup>
QB/B-92-4	-	-	-	-	-
MS/79-10	+	4.80	7.4	2.3 x 2.0	0.8 x 10 <sup>4</sup>
EB/A-304	+	8.60	-	0.6 x 0.4	-
HB-82-36	+	6.60	9.4	1.2 x 0.8	0.9 x 10 <sup>4</sup>
HB-83-185	+	6.80	9.0	1.7 x 1.2	0.8 x 10 <sup>4</sup>
HB-82-372	+	7.40	10.6	1.2 x 1.0	0.8 x 10 <sup>4</sup>
HB-83-39	+	5.40	8.8	1.6 x 1.4	1.1 x 10 <sup>4</sup>
Kufri Jyoti	+	3.80	6.2	2.5 x 1.0	1.4 x 10 <sup>4</sup>
Kufri Chandramukhi	+	3.20	5.4	2.8 x 2.6	4.3 x 10 <sup>4</sup>

\* Average of five replications

+ Late blight infection

- No infection

in pot experiment by artificial inoculation of P. infestans. Disease score was recorded on 1-9 scale after 10 and 15 days of inoculation. Data (Table 4.8) indicate that none of the potato hybrids/varieties exhibited immune reaction. However, minimum disease score was recorded on potato hybrid QB/A-9-120 (1.66) followed by QB/B-92-4 (2.66) and EB/A-304 (3.33). The disease progress was also least on hybrid QB/A-9-120 as it resulted only 0.66 increase in disease score within 5 days. In rest of the potato hybrids, the disease score ranged between 4.66 to 7.66 after 15 days of inoculation.

On the basis of disease score, potato hybrids/varieties QB/A-9-120 and QB/B-92-4 were found to be resistant whereas potato hybrid EB/A-304 was ranked as moderately resistant. Rest of the potato hybrids/varieties were ranked as susceptible and highly susceptible.

#### **4.6.3 Evaluation under field conditions**

##### **4.6.3.1 Summer crop:**

Seventeen potato hybrids/varieties were evaluated for their resistance to late blight under field conditions at Potato Development Station, Phuladhar. Data on infection rate ( $r$ ), area under disease progress curve (AUDPC), terminal disease severity (TDC) and yield were recorded. The data (Table 4.9) indicate that potato hybrid QB/A-9-120 resulted least infection rate, area under disease progress curve and terminal disease severity and significant increase in yield over the recommended varieties Kufri Jyoti and Kufri Chandramukhi (Plate I & Fig. 1). QB/B-92-4 and EB/A-

**Table 4.8** Evaluation of potato hybrids/varieties to Phytophthora infestans under green house conditions

Potato hybrid/variety	Disease score (1-9 scale) after		Reaction
	10 days	15 days	
JT-1857	4.66	6.66	S
QB/A-9-120	1.00	1.66	R
PH/F-1545	5.00	7.66	S
MS/79-34	2.66	4.33	S
PJ-376	5.00	7.00	S
JI-5857	4.33	6.33	S
MS/78-46	5.00	6.33	S
JH-222	4.66	6.66	S
QB/B-92-4	1.33	2.66	R
MS/79-10	4.33	7.00	S
EB/A-304	1.66	3.33	MR
HB-82-36	2.66	5.33	S
HB-83-185	3.66	6.00	S
HB-82-372	2.66	4.66	S
HB-83-39	4.00	6.33	S
Kufri Jyoti	5.33	7.33	S
Kufri Chandramukhi	5.33	7.66	S

\* Average of five replications

R = Resistant (1-3); MR = Moderately Resistant (> 3-4);

S = Susceptible (> 4-9)

Table 4.9 Evaluation of potato hybrids/varieties to late blight under field conditions (Summer crop)\*

Potato hybrid/variety	Infection rate (r)	Area under disease progress curve (AUDPC)	Terminal disease severity (%)	Yield (q/ha)
JT-1857	0.28	985.85	95.00 (77.08)	42.35
QB/A-9-120	0.00	1.23	0.06 (1.31)	129.85
PH/F-1545	0.28	1170.13	98.33 (85.47)	41.66
MS/79-34	0.20	70.00	11.66 (18.61)	25.00
PJ-376	0.30	678.00	95.00 (77.08)	52.07
JI-5857	0.21	546.51	73.33 (60.69)	34.71
MS/78-46	0.27	860.96	95.00 (77.08)	37.49
JH-222	0.27	923.35	95.00 (77.08)	22.91
QB/B-92-4	0.02	4.25	1.00 (5.74)	71.24
MS/79-10	0.23	1426.78	95.00 (77.08)	15.61
EB/A-304	0.07	4.75	1.00 (5.74)	125.34
HB-82-36	0.16	498.06	58.33 (50.00)	86.80
HB-83-185	0.18	498.06	58.33 (50.00)	72.40
HB-82-372	0.20	358.53	41.66 (40.00)	114
HB-83-39	0.15	464.85	50.00 (45.00)	84.58
Kufri Jyoti	0.25	1081.40	95.00 (77.08)	45.47
Kufri Chandramukhi	0.30	1526.78	95.00 (77.08)	34.54
CD	0.07	576.00	10.67	46.98

\* Average of three replications

Figures in parentheses are angular transformed values

## PLATE I

- (a) Resistant hybrid QB/A-9-120
- (b) Moderately resistant hybrid EB/A-304
- (c) Kufri Jyoti

# PLATE-I



a



b



c

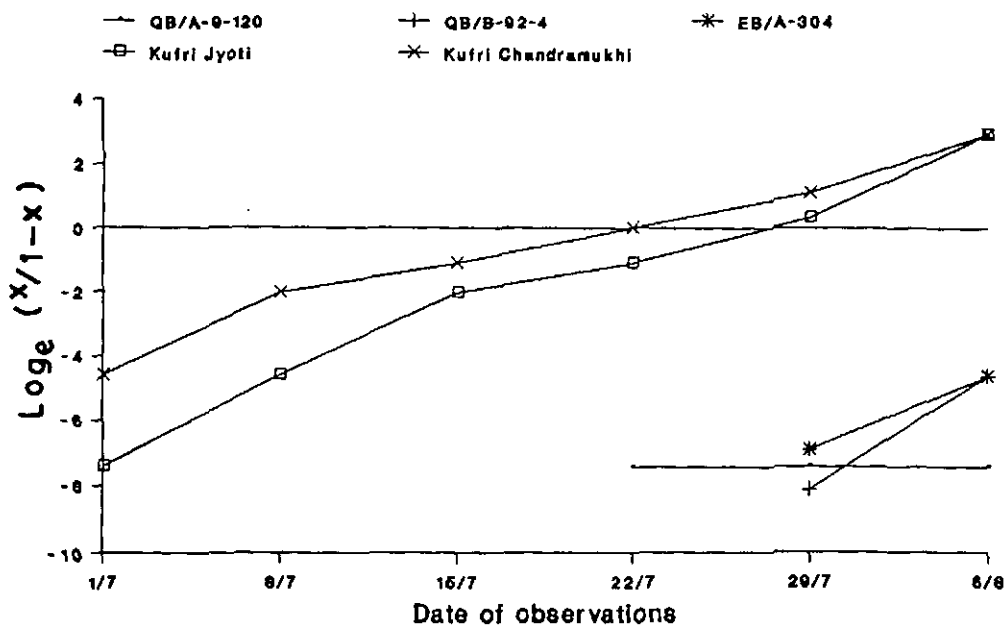
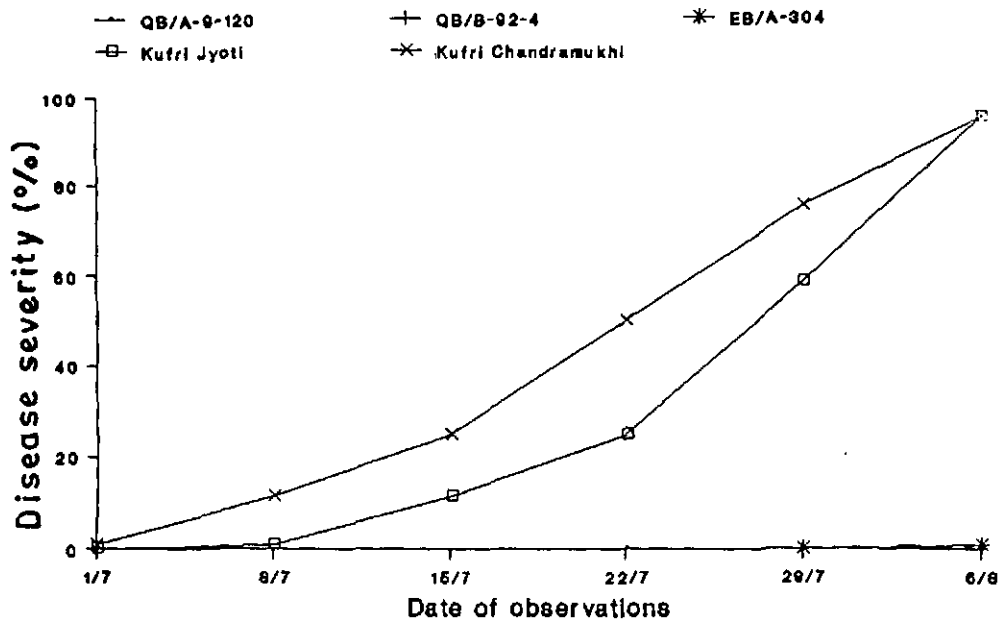


Fig.1. DISEASE PROGRESS ON FIVE POTATO GENOTYPES IN SUMMER CROP

304 (Plate I & Fig. 1) were the next best potato hybrids and did not show significant difference in their infection rate, AUDPC and terminal disease severity. However, these hybrids differ significantly in potato yield. In spite of high rate of disease development and AUDPC value, EB/A-304 gave comparable yield to QB/A-9-120. Potato hybrid QB/B-92-4 had low infection rate and AUDPC but its yield potential was poor.

Hybrids HB-83-39, HB-82-36 and HB-83-185 were almost similar in their performance as they gave no significant difference in their infection rates, AUDPCs, terminal disease severities and yield. The rate of disease development and AUDPC were low in case of potato hybrid MS/79-34 but it gave poor yield. Potato hybrid HB-82-372 gave significant reduction in AUDPC and increase in yield over Kufri Chandramukhi. AUDPC was significantly reduced in case of JI-5857 but rated at par in yield with Kufri Chandramukhi and Kufri Jyoti. In rest of the hybrids, there was no significant difference in their infection rates, AUDPC values, TDS values and yield.

#### **4.8.3.2 Spring crop:**

The potato hybrids/varieties tested for their resistance to late blight in summer crop were also evaluated in spring crop at farmer's field near Rice Research Station, Malan. The data (Table 4.10) indicate that the rate of disease progress was least in potato hybrid QB/A-9-120 as it gave infection rate of 0.03 per unit per day followed by

Table 4 10 Evaluation of potato hybrids/varieties to late blight under field conditions (Spring crop)\*

Potato hybrid/variety	Infection rate (r)	Area under disease progress curve (AUDPC)	Terminal disease severity (%)	Yield (q/ha)
JT-1857	0 19	1330 11	75 00 (60 00)	38 53
QB/A-9-120	0 03	6 53	0 36 (2 62)	118 74
PH/F-1545	0 22	1862 23	81 66 (65 69)	40 96
MS/79-34	0 21	1163 51	58 33 (50 00)	36 45
PJ-376	0 20	1711 61	81 66 (65 69)	59 36
JJ-5857	0 18	1096 90	58 33 (50 00)	48 95
MS/78-46	0 24	1827 23	88 33 (71 38)	57 63
JH-222	0 16	1566 95	75 00 (60 00)	39 22
QB/B-92-4	0 07	27 41	1 00 (5 73)	76 79
MS/79-10	0 19	1381 45	73 33 (60 69)	42 70
EB/A-304	0 12	53 19	3 66 (10 52)	124 29
HB-82-36	0 17	756 35	41 66 (40 00)	88 53
HB-83-185	0 19	1242 73	66 66 (55 00)	71 42
HB-82-372	0 16	723 56	33 33 (35 00)	89 23
HB-83-39	0 19	1096 90	58 33 (50 00)	64 79
Kufr1 Jyoti	0 21	1562 28	88 33 (70 72)	49 99
Kufr1 Chandramukhi	0 24	1784 36	88 33 (70 72)	42 57
CD (0 05)	0 06	759 0	13 66	21 73

\* Average of three replications

Figures in parentheses are angular transformed values

QB/B-92-4 (0.07) and EB/A-304 (0.12) as compared to Kufri Chandramukhi and Kufri Jyoti which gave infection rate to the tune of 0.24 and 0.21 per unit per day respectively (Fig. 2). These hybrids also showed similar trends in their disease progress curves and terminal disease severities. However, potato hybrids EB/A-304 gave maximum yield (124.29 q/ha) which was rated at par with QB/A-9-120 (118.74 q ha<sup>-1</sup>). Though the rate of disease development and AUDPC value were less in case of QB/B-92-4 but it gave poor yield. Potato hybrids HB-82-372 and HB-82-36 gave significant reduction in their infection rate and AUDPC values over the check variety Kufri Chandramukhi. These hybrids were also rated at par in their terminal disease severities. Rest of the potato hybrids did not differ significantly in their infection rates and AUDPC values as compared with recommended varieties Kufri Chandramukhi and Kufri Jyoti. However, potato hybrids HB-83-39 and HB-83-185 gave significant increase in yield.

#### **4.7 EFFECT OF DIFFERENT FUNGICIDAL SPRAY SCHEDULES ON THE MANAGEMENT OF LATE BLIGHT UNDER FIELD CONDITIONS**

##### **4.7.1 Summer crop:**

Eight spray schedule treatments of contact and systemic fungicides were tested for their efficacy in controlling late blight of potato at Potato Development Station Phuladhar. Data on infection rate (r), area under disease progress curve (AUDPC), terminal disease severity and yield were recorded in different treatments and economics of

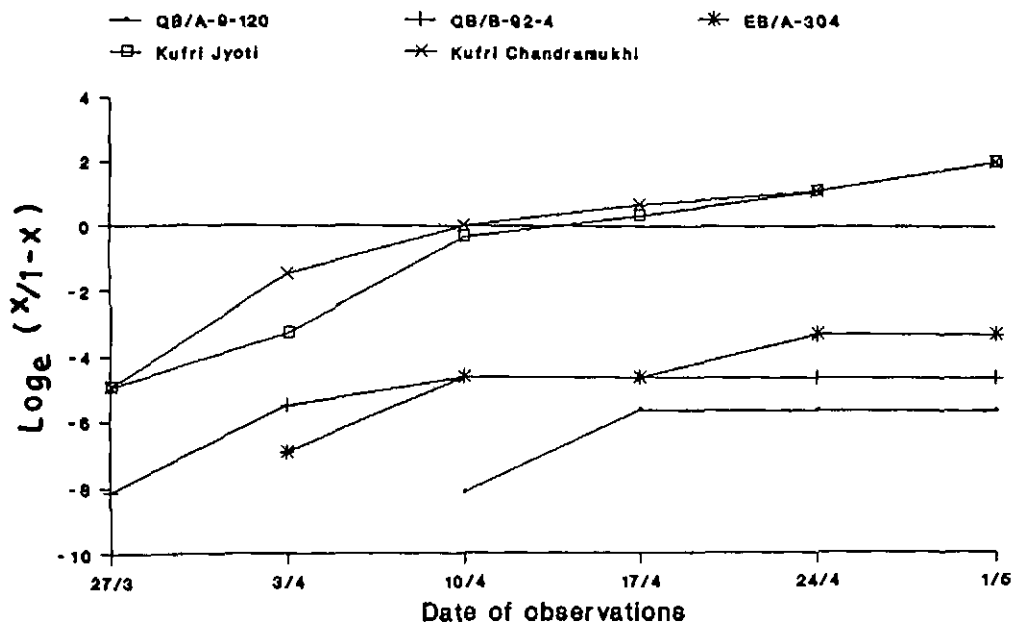
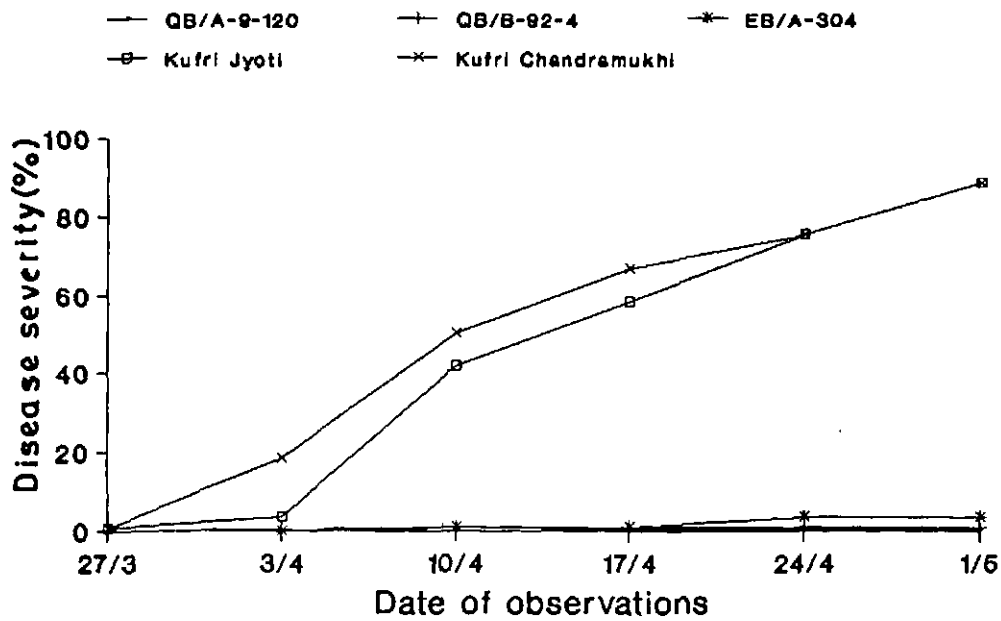
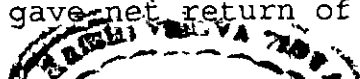


Fig.2. DISEASE PROGRESS ON FIVE POTATO GENOTYPES IN SPRING CROP

different spray schedules were calculated on hectare basis. Data (Table 4.11) reveal that all the test treatments were significantly superior to the unsprayed check in reducing area under disease progress curve, terminal disease severity and increasing yield. However, two sprays of Ridomil MZ @0.25% + three sprays of Indofil M-45 @0.25% (S,P,S,P,P) were most efficacious as they gave infection rate, AUDPC, terminal disease severity and yield to the tune of 0.12 per unit per day, 53.19, 3.67 per cent and 201.38 q ha<sup>-1</sup> as compared to unsprayed plots where infection rate, AUDPC, terminal disease severity and yield were to the tune of 0.26 per unit per day, 1214.95, 96.66 per cent and 34.26 q ha<sup>-1</sup> respectively (Plate II). Five sprays of Previcur N alone @0.25% was the next best treatment followed by three sprays of Blitox-50 @0.3% + two sprays of Ridomil MZ @0.25% (P,S,P,S,P) and five sprays of Previcur N + Indofil M-45 @0.18% + 0.16%. These treatments were rated at par in their infection rates and AUDPC values. Five sprays of Previcur N alone gave significant increase in yield over the latter two treatments. Five sprays of Indofil M-45 alone @0.25% were found to be least effective.

The economics of application of different fungicidal spray schedules at the current market price shown (Table 4.12) indicate that two sprays of Ridomil MZ @0.25% + three sprays of Indofil M-45 @0.25% realized highest net return of Rs. 32965.00 ha<sup>-1</sup>. Three sprays of Blitox-50 + two sprays of Ridomil MZ gave net return of Rs. 22834.00 ha<sup>-1</sup> followed by



## PLATE II

(a) Two sprays of Ridomil MZ @0.25% + three sprays of  
Indofil M-45 @0.25% (S,P,S,P,P)

(b) No spray

# PLATE-II



Table 4 12 Economic analysis of spray schedules for the management of late blight of potato (summer crop)

Treatment	Concentration (%)	Quantity of fungicide required/ha (kg)	Cost of fungicide (Rs)*	Labour expenses (Rs)**	Yield (q/ha)	Additional yield (q/ha)***	Additional income/ha (Rs)***	Total expenditure/ha (Rs)	Net income/ha (Rs)
Blitox-50 + Ridomil MZ (3 sprays)	0 30 + 0 25	9 00+5 00	1566 00+6830 00 = 8396 00	600 00	161 57	127 32	31830 00	8996 00	22834 00
Indofin M-45 + Ridomil MZ (4 sprays)	0 25 + 0 25	10 00+2 50	1850 00+3415 00 = 5265 00	600 00	140 61	106 36	26590 00	5865 00	20725 00
Ridomil MZ + Indofin M-45 (2 sprays)	0 25 + 0 25	6 00+7 50	6830 00+1387 50 = 8217 50	600 00	201 38	167 13	41782 50	8817 50	32965 50
SAN518 + Difolatan (1 spray)	0 25 + 0 25	2 50+10 00	1750 00+3740 00 = 5490 00	600 00	109 90	75 65	18912 50	6090 00	12822 50
Chlorothalonil + Ridomil MZ (4 sprays)	0 25 + 0 25	10 00+2 50	4500 00+3415 00 = 7915 00	600 00	146 06	111 81	27952 50	8515 00	19437 50
Previcur N (5 sprays)	0 25	12 50	(T F)						
Indofin M-45 (5 sprays)	0 25	12 50	2312 50	600 00	101 63	67 38	16845 00	2912 50	13932 50
Previcur + Indofin M-45 (5 sprays)	0 18 + 0 16	9 00+8 00	(T F)						
Control	-	-	-	-	34 25	-	-	-	-

\* Cost of fungicides

SAN518 = Rs 700/kg  
 Ridomil MZ = Rs 1366/kg  
 Indofin M-45 = Rs 185/kg  
 Blitox-50 = Rs 174/kg

Chlorothalonil = Rs 450/kg  
 Difolatan = Rs 374/kg  
 TF = Test Fungicide

\*\*\* Prevalent market rate of produce Rs 250/quantal

four sprays of Indofil M-45 + one spray of Ridomil MZ (Rs. 20725.00 ha<sup>-1</sup>). One spray of SAN518 + four sprays of Difolatan gave least net return (Rs. 12822.50/- ha<sup>-1</sup>) and rated at par with five sprays of Indofil M-45 alone. Though Previcur N alone and its combination with Indofil M-45 was quite effective in field trial but its economics could not be worked out as it is a test fungicide.

#### **4.7.2 Spring crop:**

The same spray schedule treatments were further evaluating in spring crop at farmer's field near Rice Research Station, Malan. Observations on infection rate, area under disease progress curve, terminal disease severity and yield were recorded and economics of different spray schedule treatments were calculated. Data (Table 4.13) reveal that the trend of effectiveness of all treatments tested in summer crop was almost similar in spring crop, however, the yields in various treatments were comparatively higher than summer crop. Two sprays of Ridomil MZ + three sprays of Indofil M-45 (S, P, S, P, P) were found most efficacious followed by five sprays of Previcur N alone, three sprays of Blitox-50 + two sprays of Ridomil MZ (P, S, P, S, P), five sprays of Indofil M-45 alone and one spray of SAN518 + four sprays of Difolatan (S, P, P, P, P). These treatments did not show significant difference in their infection rates of disease development. However, the latter three were rated at par in their area under disease progress curve values which differ significantly from the former two

Table 4.13 Management of late blight of potato by different fungicidal spray schedules under field conditions (Spring crop)\*

Treatment	Concentration (%)	Infection rate (r)	Area under disease progress curve (AUDPC)	Terminal disease severity (%)	Yield (q/ha)
Blitox-50 (3 sprays)	0.3	0.14	328.28	28.33 (31.14)	153.12
+ Ridomil MZ (2 sprays) (P.S.P.S.P)	0.25				
Indofil M-45 (4 sprays)	0.25	0.20	700.13	41.66 (40.00)	127.76
+ Ridomil MZ (1 spray) (P.P.S.P.P)	0.25				
Ridomil MZ (2 sprays)	0.25	0.13	42.16	3.66 (10.52)	190.33
+ Indofil M-45 (3 sprays) (S.P.S.P.P)	0.25				
SAN 518 (1 spray)	0.25	0.16	319.58	33.33 (35.00)	176.73
+ Difolatan (4 sprays) (S.P.P.P.P)	0.25				
Chlorothalonil (4 sprays)	0.25	0.20	485.13	36.66 (36.14)	120.48
+ Ridomil MZ (1 spray) (P.S.P.P.P)	0.25				
Previcur N (5 sprays)	0.25	0.14	150.53	11.66 (18.61)	195.13
Indofil M-45 (5 sprays)	0.25	0.18	408.31	36.66 (36.14)	185.13
Previcur N + Indofil M-45 (5 sprays)	0.18 + 0.16	0.17	322.63	28.33 (31.14)	136.45
Control	-	0.24	1218.95	88.33 (71.38)	87.83
CD (0.05)		0.06	244.60	13.92	34.24

\* Average of three replications

Figures in parentheses are angular transformed values

S = Systemic

P = Protectant

treatments. Two sprays of Ridomil MZ + three sprays of Indofil M-45 gave significant increase in yield and rated at par with five sprays of Previcur N and five sprays of Indofil M-45. Four sprays of Chlorothalonil + one spray of Ridomil MZ (P,S,P,P,P) and 4 sprays of Indofil M-45 + 1 spray of Ridomil MZ were least effective.

The economics of fungicidal spray schedule (Table 4.14) indicate that five sprays of Indofil M-45 alone gave highest net returns of Rs. 28710.00 ha<sup>-1</sup> followed by two sprays of Ridomil MZ + three sprays of Indofil M-45 (Rs. 24395.00 ha<sup>-1</sup>). Four sprays of Chlorothalonil + one spray of Ridomil MZ gave least net returns (Rs. 2096.25 ha<sup>-1</sup>).

The rate of disease development and area under disease progress curve were higher in case of sprays of Indofil M-45 than rest of the treatments but yield was comparatively higher than most of the treatments.

#### **4.8 INTEGRATED MANAGEMENT**

##### **4.8.1 Effect of tuber treatment + fungicide sprays on late blight development:**

A field trial was conducted at Potato Development Station Phuladhar to see the integrated effect of tuber treatment (TT) + sprays of fungicides on the development of late blight of potato. Observations on disease appearance on foliage, infection rate, area under disease progress curve (AUDPC), terminal disease severity and yield were recorded. A perusal of data (Table 4.15) indicate that TT with Ridomil MZ (0.2%) delayed the late blight appearance by 3.67 to 11.0

Table 4.14 Economic analysis of fungicidal spray schedules for the management of late blight of potato (Spring crop)

Treatment	Concentration (%)	Quantity of fungicide required/ha (kg)	Cost of fungicide (Rs)*	Labour expenses (Rs)**	Yield (q/ha)	Additional yield (q/ha)	Additional income/ha (Rs)***	Total expenditure/ha (Rs)	Net income/ha (Rs)
Blitox-50 + Ridomil MZ (3 sprays) (2 sprays)	0.30 + 0.25	9.00+5.00	1566.00+6830.00 = 8396.00	600.00	153.12	65.29	21219.25	8996.00	12223.25
Indofinil M-45 + Ridomil MZ (4 sprays) (1 spray)	0.25 + 0.25	10.00+2.50	1850.00+3415.00 = 5265.00	600.00	127.76	39.93	12977.25	5865.00	7112.25
Ridomil MZ + Indofinil M-45 (2 sprays) (3 sprays)	0.25 + 0.25	6.00+7.50	6830.00+1387.50 = 8217.50	600.00	190.33	102.50	33212.50	8817.50	24395.00
SANS18 + Difolatan (1 spray) (4 sprays)	0.25 + 0.25	2.50+10.00	1750.00+3740.00 = 5490.00	600.00	176.73	88.90	28892.50	6090.00	22802.50
Chlorothalonil + Ridomil MZ (4 sprays) (1 spray)	0.25 + 0.25	10.00+2.50	4500.00+3415.00 = 7915.00	600.00	120.48	32.65	10611.25	8515.00	2096.25
Previcur N (5 sprays)	0.25	12.50	(T.F.)						
Indofinil M-45 (5 sprays)	0.25	12.50	2312.50	600.00	185.13	97.30	31622.50	2912.50	28710.00
Previcur + Indofinil M-45 (5 sprays)	0.18 + 0.16	9.00+8.00	(T.F.)						
Control	-	-	-	-	87.83	-	-	-	-

\* Cost of fungicides

SANS18 = Rs 700/kg  
 Ridomil MZ = Rs 1366/kg  
 Indofinil M-45 = Rs 185/kg  
 Blitox-50 = Rs 174/kg

Chlorothalonil = Rs 450/kg  
 Difolatan = Rs 374/kg  
 TF = Test Fungicide

\*\* Labour charges calculated @ Rs 24/day and 5 labourers were engaged for single spray in one hectare  
 \*\*\* Prevalent market rate of produce Rs 325/quintal

Table 4 15 Management of late blight of potato by tuber treatment and sprays of fungicides under field conditions\*

Treatment	Disease appearance after planting (days)	Infection rate (r)	Area under disease progress curve (AUDPC)	Terminal disease severity (%)	Yield (q/ha)
TT + Indofil M-45 (1 spray)	80 33	0 26	974.89	88.33 (71 38)	78.28
TT + Ridomil MZ (1 spray)	82 00	0.24	312.33	41.66 (40.00)	169 05
TT + Indofil M-45 (2 sprays)	84 33	0.16	713.33	66.66 (59 88)	85 52
TT + Indofil M-45 (3 sprays)	77 66	0 19	699 06	66.66 (59.88)	105 41
TT + Indofil M-45 (1 spray) + Ridomil (1 spray)	77 00	0 27	538 01	58 33 (50.00)	195.13
TT + Indofil M-45 (5 sprays)	79 33	0 26	684.89	66.66 (59.88)	109 62
TT only	79 33	0 30	1006 68	91 66 (79.77)	48 46
Untreated + plain water spray	73 33	0 30	1452.11	100 00 (89.67)	31 17
CD (0 05)	2 78	0 10	419 70	32 02	15 60

\* Average of three replications

Figures in parentheses are angular transformed values

Sprouted tubers were treated by dipping in 0.2% fungicide suspension of Ridomil MZ for 30 minutes

Sprays of Ridomil MZ and Indofil M-45 were given @ 0.25% with the appearance of disease.

days compared with untreated tubers. TT + one spray of Ridomil MZ @0.25% was found to be most effective in reducing infection rate and AUDPC (Plate III) followed by TT + one spray of Indofil M-45 @0.25% + one spray of Ridomil MZ @0.25% and TT + five sprays of Indofil M-25 @0.25% were rated statistically at par with each other. However, maximum yield was recorded in TT + one spray of Indofil M-45 + one spray of Ridomil MZ followed by TT + one spray of Ridomil MZ and TT + five sprays of Indofil M-45. The former treatment differ significantly in yield from the latter two treatments. Tuber treatment alone resulted minimum yield and delayed the onset of disease by six days compared with untreated tubers. The rate of disease development was same in TT alone and untreated tubers, however, TT alone reduced the AUDPC value and gave an increase in yield over control.

TT + foliar sprays of Ridomil MZ and Indofil M-45 reduced the disease development, area under disease progress curve and resulted increase in yield.

#### **4.8.2 Effect of host resistance and fungicides on late blight development:**

Three potato hybrids/varieties varying in degree of resistance were planted at Potato Development Station Phuladhar and sprays of protectant and systemic fungicides were given with the appearance of disease. Unsprayed varieties were kept as check. Data on infection rate, area under disease progress curve (AUDPC), terminal disease severity and yield were recorded. The data (Table 4.16)

### PLATE III

- (a) Tuber treatment (Ridomil MZ 0.2%) + one spray of  
Ridomil MZ (0.25%)
  
- (b) Tuber treatment only (Ridomil MZ 0.2%)

# PLATE - III



a



b

Table 4.16 Integrated management of potato late blight by host resistance and fungicides\*

Variety	Fungicide	Number of sprays	Infection rate (r)	Area under disease progress curve (AUDPC)	Terminal disease severity (%)	Yield (q/ha)
QB/A-9-120 (R)	Indofil M-45 @0.25%	1	0.00	0.38	0.06 (1.31)	138.26
QB/A-9-120	Ridomil MZ @0.25%	1	0.00	0.00	0.00 (0.33)	150.34
QB/A-9-120	-	-	0.00	1.00	0.03 (0.82)	127.42
EB/A-304 (MR)	Indofil M-45 @0.25%	2	0.15	30.96	3.66 (10.52)	124.92
EB/A-304	Ridomil MZ @0.25%	2	0.09	20.86	2.00 (6.83)	145.96
EB/A-304	-	-	0.18	48.39	5.00 (12.92)	110.41
Kufri Jyoti (S)	Indofil M-45 @0.25%	5	0.23	691.13	83.33 (74.77)	100.12
Kufri Jyoti	Ridomil MZ @0.25%	3	0.15	390.23	41.66 (40.00)	139.42
Kufri Jyoti	-	-	0.26	1158.45	100.00 (89.67)	57.97
CD (0.05)			0.03	188.10	16.29	25.46

\* Average of three replication

Figures in parentheses are angular transformed values

R - Resistant variety

MR - Moderately resistant variety

S - Susceptible variety

indicate that resistant potato hybrid receiving one spray of Ridomil MZ gave no disease development and maximum yield ( $150.34 \text{ q ha}^{-1}$ ) and with one spray of Indofil M-45 gave AUDPC and terminal disease severity to the tune of 0.38 and 0.06 per cent, respectively. However, Indofil M-45 sprayed and unsprayed plots of QB/A-9-120 didn't differ significantly in disease development.

Moderately resistant hybrid EB/A-304 receiving two sprays of Ridomil MZ gave significant reduction in infection rate, however, the area under disease progress curve, terminal disease severity and yield did not differ significantly from the plots receiving two sprays of Indofil M-45.

Susceptible variety Kufri Jyoti receiving three sprays of Ridomil MZ gave significant reduction in infection rate, AUDPC, terminal disease severity as compared to plots receiving five sprays of Indofil M-45 and unsprayed check Kufri Jyoti sprayed with Ridomil MZ also gave significant increase in yield.

In general resistant variety receiving one spray of Ridomil MZ and moderately resistant variety receiving two sprays of Ridomil MZ show no significant difference in AUDPC, terminal disease severity and yield. Thus the moderately resistant variety could be brought to the level of resistant variety by giving two sprays of Ridomil MZ.



# DISCUSSION

## DISCUSSION

Results of present investigations will be discussed under following subheads:

5.1 Protectant and systemic fungicides

5.2 Host resistance

5.3 Spray schedule

5.4 Integrated management.

### 5.1 PROTECTANT AND SYSTEMIC FUNGICIDES

In vitro evaluation of systemic and protectant fungicides against Phytophthora infestans showed that Ridomil MZ (750 ug ml<sup>-1</sup>), SAN 518 (1000 ug ml<sup>-1</sup>) and Indofil M-45 (2000 ug ml<sup>-1</sup>) resulted complete inhibition of sporangial germination while other fungicides were comparatively less toxic at all the test concentrations. Bruck et al. (1980) also reported complete inhibition of sporangial germination of one of the isolates of P. infestans at low concentration of metalaxyl (25 ug ml<sup>-1</sup>). However, metalaxyl at same concentration failed to inhibit the sporangial germination of other isolates. Bruck et al. (1981) found suppression of sporangial germination at low concentrations of chlorothalonil and mancozeb but in the present investigation, metalaxyl and mancozeb were found effective only at higher concentrations. Differences in strains of P. infestans and use of commercial formulations of fungicides may be responsible for such variation in

results.

Spray of fungicides as pre and post inoculation of P. infestans on detached leaves of potato indicated that Ridomil MZ (0.25%), SAN 518 (0.25%) and Previcur N (0.25%) were effective in reducing the late blight development and sporulation. Pre and post inoculation sprays of Ridomil MZ completely checked the disease development. Pre inoculation spray was better in reducing per cent leaf area infected as well as sporulation than post inoculation spray of all fungicides under test. These results reveal that time of application of fungicide has a significant influence on the efficacy of various fungicides. Ridomil MZ, a specific systemic fungicide could significantly control the disease even at highest disease pressure, as pre and post infection sprays. On the other hand poor control of the disease was obtained with post infection spray of other fungicides. These findings are in agreement with those of Thind et al. (1989). Ridomil MZ, SAN 518 and Previcur N gave almost similar results when tested under green house conditions. Indofil M-45 was better than chlorothalonil when applied both as pre and post inoculation sprays. These results are in confirmation with the findings of Bruck et al. (1980, 1981) and Thind et al. (1989). Bhattacharyya et al. (1987) reported complete protection of host tissue by P. infestans when oxadixyl + mancozeb (0.2%) was sprayed 24 and 48 hours after inoculation.

Tubers carrying 5 and 10 per cent surface area infected

with blight lesion had no effect on tuber germination, disease transmission and development. However, tubers having 15, 20 and 25 per cent infection levels gave 60 to 90 per cent germination and late blight development in potted plants. Boyd (1980) also observed more than 80 per cent germination of blight infected seed tubers and development of haulm infection. He confirmed the development of infection from tubers by inoculating with a complex race of P. infestans and the same race was recovered from the infected haulms and leaves, however, he has not mentioned the level of infection in the infected tubers. In the present studies tubers carrying 15 and more than 15 per cent surface area covered by blight lesion gave the development of disease. This has a significant bearing in the epidemiology of late blight especially where the infection initiates from tubers. Results of tuber treatment with fungicides also indicated that Ridomil MZ @0.2% was most efficacious in controlling lesion development followed by SAN 518 (0.2%) and Aliette (0.2%). Tubers dipped for 30 and 60 minutes in fungicidal suspension did not show significant difference in lesion development. Singh and Bhattacharyya (1988, 1990) also reported that tuber treatment with metalaxyl was comparatively better over oxadixyl at all the test concentrations and dip intervals. However, their results varied with the levels of tuber infection and methods of treatment. Tuber dip in metalaxyl suspension (0.2%) for 30 minutes has been reported effective in

arresting the lesion development (Anonymous, 1992).

Ridomil MZ (0.2%) treated tubers gave protection of sprouts from infection upto 19 days whereas, SAN 518 (0.2%) and Aliette (0.2%) gave protection upto 15 and 11 days, respectively. Indofil M-45 (0.25%) was least effective (Table 4.6). However, Bhattacharyya *et al.* (1983) reported that none of the plants raised from metalaxyl treated tubers developed infection upto 10 and 18 days at 0.06 and 0.1 per cent concentrations, respectively. In the present studies high infection level (20%) of tubers treated with metalaxyl (0.2%) could give protection upto 19 days. This may be due to high level of tuber infection and use of higher concentration of fungicide.

#### 5.4 HOST RESISTANCE

Results of evaluation of potato hybrids/varieties for their resistance to *P. infestans* on detached leaves under laboratory and potted plants under glass house conditions revealed high degree of resistance in hybrids QB/A-9-120 and QB/B-92-4. Hybrid EB/A-304 was also equally resistant where though infection developed after 8.6 days with a lesion size of 0.6 x 0.4 cm but no sporulation occurred. Singh *et al.* (1988) evaluated 337 potato genotypes for their resistance components viz., incubation period, infection efficiency, colonization and sporulation. Five genotypes CP 1880, 2016, 2013, 1673 and 2053 were found to carry all the four components of field resistance. Present studies also revealed that potato hybrids QB/A-9-120, QB/B-92-4 and EB/A-

304 also carry the rate reducing components of field resistance. Their ability to reduce sporulation completely is the most important component for determining field resistance (Birhman et al., 1989). On the basis of disease score and reaction types, QB/A-9-120 and QB/B-92-4 were designated as resistant and EB/A-304 as moderately resistant.

Results of evaluation of potato hybrids/varieties for their resistance to late blight under field conditions in summer and spring crops also indicated that infection rate, area under disease progress curve and terminal disease severity were least in QB/A-9-120 followed by QB/B-92-4 and EB/A-304. The present results are in confirmation to the findings of Sharma (1994) who observed QB/A-9-120 and QB/B-92-4 to be highly resistant and EB/A-304 as resistant. Apart from resistance to P. infestans, hybrids QB/A-9-120 and EB/A-304 yielded significantly higher than recommended variety Kufri Jyoti. The higher yield vigour exhibited by QB/A-9-120 is due to its cross combination S. tuberosum ssp. andigena (JEX/A-680-16) x S. tuberosum ssp. tuberosum (Kufri Jyoti). The female parent JEX/A-680-16 is adapted to short day conditions and possesses a wider genetic variability (Sikka, 1977). The yield performance of QB/B-92-4 was considerably low due to non adaptability of this hybrid to long day conditions of high hills.

The expression of late blight resistance varied in different hybrids/varieties. In cultivar Kufri Jyoti and

hybrids JI-1857, PH/F-1545, MS/79-34. PJ-376, JI-5857, MS/78-46, JH-222, MS/79-10, HB-82-36, HB-83-185, HB-82-376 and HB-83-39, late blight progressed at a higher rate and had more area under disease progress curves (Table 4.9 and 4.10). These hybrids carry R-gene resistance which is invariably not durable. QB/A-9-120 showed high degree of resistance to P. infestans. Its female parent JEX/A-680-16 ssp. andigena has minor gene resistance (Sikka, 1977) but the male parent Kufri Jyoti carries R-gene resistance. This indicates that in all likelihood QB/A-9-120 has base dose of vertical resistance to the common races superimposed with horizontal resistance. This combination escaped the early infection and its later build up to a great extent. The results indicated that QB/A-9-120 possessed a high degree of minor and major gene resistance to P. infestans and hence it can slash the use of fungicides and had high potential for main crop. Stability of late blight resistance in this hybrid has also been reported (Sharma, 1994). Potato hybrids QB/A-9-120, QB/B-92-4 and EB/A-304 possessed good level of resistance to late blight and yielded significantly higher than Kufri Jyoti both in summer and spring crop. Thus these have adaptability to short as well as long day conditions.

### 5.3 SPRAY SCHEDULE

Results of field trials conducted with different spray schedules of protectant and systemic fungicides for developing an effective and economic spray schedule against late blight indicated that two sprays of Ridomil MZ @0.25% +

three sprays of Indofil M-45 @0.25% in the sequence of S, P, S, P, P was most efficacious in containing the disease and significantly improved tuber yields. Five sprays of Previcur N alone (0.25%) was the next best treatment followed by three sprays of Blitox-50 + two sprays of Ridomil MZ (P, S, P, S, P). Earlier workers have also reported the effectiveness of metalaxyl and Indofil M-45 from different places (Misra et al., 1987; Vishwanathappa et al., 1988; De and Hossain et al., 1990 and Mohasin, 1993). However, there is no information in different spray schedules of protectant and systemic fungicides. One spray of Ridomil MZ (0.25%) alternated with two sprays of Indofil M-45 have been reported highly effective and economic for the control of late blight in the North Western plains of India in the years of an early disease outbreak (Sharma, 1994). Two sprays of Ridomil MZ and four sprays of Indofil M-45 have been recommended to contain potato late blight in hills as crop duration is more (5-6 months) as compared to plains where crop remains for 3-4 months. However, in years of low disease pressure mancozeb sprays at 10 day intervals have been found useful in combating disease in plains of India (Sharma, 1992). In the present studies five sprays of Indofil M-45 alone failed to control the disease in hills (summer crop) but effectively controlled the disease in spring crop. The difference in effectiveness of Indofil M-45 in different crop seasons is due to high precipitation in summer crop resulting in washing off of fungicide as

compared to low precipitation in spring crop. Though five sprays of Previcur N (0.25%) alone also gave good level of disease control, but its performance against sporangial germination was poor. Similar results have been reported from other countries by Samoucha and Cohen (1990) and Lochel and Birchmore (1990).

The economic analysis of data of summer crop (Table 4.12) and spring crop (Table 4.14) indicated that two sprays of Ridomil MZ + three sprays of Indofil M-45 were most economic in summer crop. However, in spring crop five sprays of Indofil M-45 was most economic. Conventional fungicide Indofil M-45 may be useful in combating blight in spring crop due to its low cost and also not inducing resistant strains. Sharma (1992) and Prasad (1994) have also reported economic use of mancozeb in plains of India in the years of low disease pressure. One spray of Ridomil MZ alternated with subsequent sprays of Indofil M-45 have been reported to give complete and economic control of potato late blight during high disease pressure in plains (Sharma, 1994). In present studies two sprays of Ridomil MZ + three sprays of Indofil M-45 (S, P, S, P, P) gave effective and economic control of blight in hills (summer crop) as the disease pressure was very high. Keeping in view the risk of fungal resistance to systemic fungicides (Moore, 1949; Singh et al., 1988) this spray schedule is safer as it involved two sprays of systemic fungicides and that too in the mixture formulation of systemic and contact fungicides and three

sprays of Indofil M-45. The weather conditions are entirely different in spring crop and disease pressure is generally low, hence, individual sprays of Indofil M-45 were effective and economic in combating the disease. Five sprays of Previcur N alone (0.25%) gave good control of disease both in summer and spring crop, however, being a test fungicide no economic analysis could be made. Previcur N could be economical if its cost is comparatively less than Ridomil MZ especially in combination with protectant fungicides.

#### **5.4 INTEGRATED MANAGEMENT**

Results of integrated effect of tuber treatment + foliar spray of fungicide (Table 4.15) showed that tuber treatment with Ridomil MZ + one spray of Ridomil MZ was found most effective in reducing the progress of late blight. However, tuber treatment + one spray of Indofil M-45 + one spray of Ridomil MZ gave maximum yield (195.13 q/ha), though disease progress was comparatively more. The possible reason for increase in yield could be due to extra supply of zinc by giving additional spray of Indofil M-45. Tuber treatment alone delayed the onset of blight by 3.67 to 11 days compared with untreated tubers. These results indicate the importance of reducing initial inoculum which later on delays the epidemic of disease. Hartill (1980) reported that tubers treated with metalaxyl and milfuram did not develop symptoms of late blight until the flowering stage of the crop and subsequent disease progress was slow. Singh and Bhattacharyya (1990) reported that plants raised from

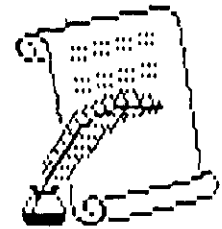
metalaxyl treated tubers did not show any late blight symptoms upto 90 days in humid chambers. In the present studies the effect of tuber treatment alone could not be ascertained till flowering/maturity of crop due to cross inoculations from adjoining potato fields.

Sprays of fungicides to potato hybrids/varieties having different degrees of resistance (Table 4.16) indicated that integration of host resistance and fungicidal sprays significantly reduced the infection rate, area under disease progress curve, terminal disease severity and improved tuber yields. Plots of potato hybrid QB/A-9-120 sprayed with Ridomil MZ or Indofil M-45 did not show significant difference in disease development. Similarly, two sprays of Ridomil MZ or Indofil M-45 given to moderately resistant hybrid EB/A-304 had no significant difference in area under disease progress curves, terminal disease severities and yields. However, plots receiving two sprays of Ridomil MZ show significant difference in infection rate and yield compared with unsprayed plots of EB/A-304. Susceptible cultivar Kufri Jyoti receiving three sprays of Ridomil MZ were superior than five sprays of Indofil M-45. However, these two treatments had significant effect in reducing area under disease progress curve and terminal disease severity and increasing yield compared with unsprayed plots.

These results highlight the importance of fungicides as component of integrated management especially with moderately resistant cultivars. Fry (1978) reported that

general resistance and fungicide application both reduced disease and the effect of each was additive. Olofsson (1992) concluded that one spray of mancozeb ( $1.5 - 2.0 \text{ kg ha}^{-1}$ ) to moderately resistant potato cultivar gave adequate control of late blight. However, in the present studies two sprays of Ridomil MZ to moderately resistant hybrid gave significant reduction in infection rate and increase in yield.





# SUMMARY

## Chapter 6

### SUMMARY

The results of studies on management of late blight of potato revealed that:

Three fungicides namely, Ridomil MZ ( $750 \text{ ug ml}^{-1}$ ), SAN 518 ( $1000 \text{ ug ml}^{-1}$ ) and Indofil M-45 ( $2000 \text{ ug ml}^{-1}$ ) gave complete inhibition of sporangial germination of Phytophthora infestans. Similarly, Ridomil MZ (0.25%) and SAN 518 (0.25%) as pre and post inoculation sprays were found highly effective on detached leaves and potted plants under green-house conditions. Previcur N also gave good level of disease control, though, its performance was poor in inhibiting sporangial germination. Pre inoculation sprays of all the fungicides were better than post inoculation sprays under all test conditions.

Tubers carrying 15 per cent level of infection and above adversely affected the germination and transmitted the disease in potted plants. Tuber treatment of artificially inoculated tubers with Ridomil MZ (0.2%) for 60 minutes was most effective in arresting lesion development followed by SAN 518 and Aliette. However, Indofil M-45 was least effective. Dip intervals of 30 and 60 minutes did not show significant difference in inhibiting blight lesion development. However, fungicide concentrations (0.2 and 0.1%) showed significant difference in inhibiting lesion development. Ridomil MZ treated tubers were free from

sprout infection upto 19 days, where as, SAN 518 and Aliette gave protection upto 15 and 11 days, respectively.

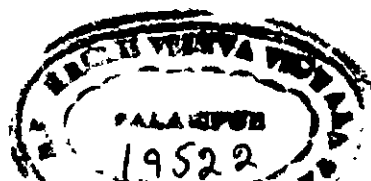
Potato hybrids QB/A-9-120 and QB/B-92-4 showed resistant reaction, where as, potato hybrid EB/A-304 gave moderately resistant reaction both under laboratory and field conditions in summer and spring crop. Potato hybrids QB/A-9-120 and EB/A-304 also gave significant increase in yield over Kufri Jyoti and Kufri Chandramukhi. However, QB/B-92-4 was a poor yielder both in summer and spring crop.

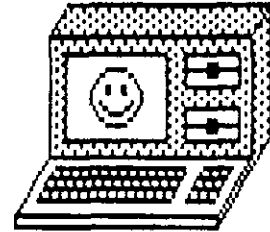
Two sprays of Ridomil MZ (0.25%) + three sprays of Indofil M-45 (0.25%) in the sequence of S, P, S, P, P were most efficacious in controlling late blight in summer as well as in spring crop. This spray schedule gave highest net return of Rs. 32965.00/ha and found most economic in summer crop. However, five sprays of Indofil M-45 were economical for managing late blight in spring crop, though, it was less effective than two sprays of Ridomil MZ + three sprays of Indofil M-45. Five sprays of Previcur N (0.25%) alone gave good control of disease both in summer and spring crop. However, being a test fungicide, no economic analysis could be made.

Tuber treatment with Ridomil MZ (0.2%) for 30 minutes + one foliar spray of Ridomil MZ was found most efficacious in containing late blight of potato. However, maximum yield was obtained with tuber treatment + one spray of Indofil M-45 + one spray of Ridomil MZ.

Resistant hybrid (QB/A-9-120) receiving one spray of

Indofil M-45 or Ridomil MZ did not show significant difference in disease development over unsprayed plots. However, moderately resistant hybrid (QB/A-304) receiving two sprays of Ridomil MZ resulted significant reduction in infection rate and increase in yield compared with unsprayed plots of EB/A-304. Susceptible cultivar (Kufri Jyoti) receiving three sprays of Ridomil MZ or five sprays of Indofil M-45 gave significant reduction in area under disease progress curve, terminal disease severity and increase in yield over unsprayed plots.





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## LITERATURE CITED

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