CHAPTER XII

STUDIES ON RELATIVE EFFICACY OF CERTAIN FUNGICIDES
ON SURVIVAL, GROWTH AND DEVELOPMENT OF P. INFESTANS.

Control of plant diseases aims at prevention or reduction of disease occurrence and is usually concerned at population rather than individual level. Complete eradication of a pathogen from the crop has never been possible but is attempted as an aid to achieve the above aims. Agrios (1978) stated "... considering the regularity with which most serious diseases of crop plants appear in an area year after year, the rapidity of spread of most plant diseases and the difficulties, when at all possible, in curing a disease after it has began to develop, it is easy to understand why almost all control methods are aimed at protecting plants from becoming diseased rather than at curing them after they have become diseased..."

The most commonly known means of controlling plant diseases is through the use of chemical substances, that are toxic to the pathogen. Such chemicals either inhibit germination, growth and multiplication of the pathogen or becomes outright lethal to the pathogen. Most of the chemicals are used to control diseases of the foliage and of other above ground parts of plants. Others are used to disinfest and protect from infection of seeds, tubers and bulbs. Some are used to disinfest the soil, others to disinfest ware house, to treat wounds or to protect stored fruit and vegetables from infection. Some chemicals, however, do have a therapeutic action and several new chemicals such as systemic fungicides and antibiotics are absorbed
and systemically translocated by the plant.

Late blight disease of potato, caused by *Phytophthora infestans* is by far the most serious diseases of potato and a lot of experimental works have been in progress in all parts of the world to find out suitable measures to control the disease. In India, a number of fungicides have been tested by a large number of workers, in the hills as well as plains and the efficacy of different fungicides was found to vary from place to place depending on the climate. Vasudeva and Azad (1952) conducted experiments during 1948-49 at Kufri in the Simla hills and found Burgandy mixture to give the best results in the control of late blight. Chattopadhyaya (1952) reported Dithane D-14 (1/4 gal/100 gals water + 1 1/2 lb zine sulphate and 1/2 lb lime) and Dithane Z-78 (2 lb to 100 gals) to be fairly tenaceous in the hills of Darjeeling district, West Bengal. Mehta and Singh (1953) found 1.0 percent Bordeaux mixture, 3.0 percent Perenox, 0.1 percent yellow Cuproside or Dithane Z-78 to give good control in Uttar Pradesh. Choudhury (1954) found Perenox (1.25 lb/100 gals) to be highly effective in controlling the disease, along with Dithane in Darjeeling district. Dutt (1962, 67) found Bordeaux mixture to give better results than all other fungicides in Simla hills, Uttar Pradesh. Paharia (1961) tried different fungicides at Patna, Bihar and found Dithane Z-78 to give good results. In the Nilgiris, Thyagrajan (1965) tested the efficacy of Cuman for the control of late blight and found that 0.1 percent Cuman gave better control and increased the
yield by 29.7 percent over Bordeaux mixture. Azariah and Rai (1970) found Maneb to give better results than Zineb and Bordeaux mixture with spray intervals of 6 days in the Nilgiris. The experiments conducted at the Central Potato Research Institute, Ootacamond, have shown that the blight could be effectively controlled by spraying the crop with Fycol 8 E (3125 ml/ha), Dithane Z-78 or Dithane M-45 (2 kg/ha) or Brestan (600 g/ha) (Dutt et al., 1969, 70). The field trials at Pantnagar (U.P.) have shown Dithane M-45 to give best results followed by Dithane Z-78, Blitane, Blitox, Lonacol, Zirum, Miltox and Fycol E (Singh et al., 1969, 70).

In Assam, spraying trials in the hilly regions was conducted by Majid and observed Perenox to be highly effective in controlling late blight disease. Roy and Das (1968) reported that blight infection was minimum with Dithane M-45 (12 percent infection) followed by Brestan (21 percent), almost equal in Captan (28 percent) and Blitox (29 percent) and maximum in Cuman (58 percent).

Systemic fungicides are now extensively used by several workers in controlling plant diseases. Metalaxyl, a systemic fungicide, has been reported by several workers to be highly effective against late blight disease (Bruck et al., 1981; Bhatia, 1983; Easton and Nagle, 1984). However, no report has so far been made on the effectiveness of this fungicide against late blight in India. Likewise, Benomyl, another systemic fungicide has been reported to be highly effective against a
large number of plant pathogens (Edgington et al., 1971; Malhan et al., 1975; Bateman, 1984).

It is obvious that the effectiveness of chemicals used for the control of late blight disease of potato vary from place to place depending on various ecological conditions. Although sufficient trials have been made with different fungicides to control the disease in different parts of India, representing various climatic zones, very little have been reported from Assam (Mazid, 1952; Roy and Das, 1968). The present investigation deals with the effect of some fungicides against Phytophthora infestans, in the light of varying ecological conditions prevalent in the district of Lakhimpur, Assam.

Materials and methods:

In vitro tests: The efficacy of the fungicides were tested in varying concentrations against growth of P. infestans by poisoned food technique (Shukla et al., 1972). Measured quantities of fungicides were added in sterilised Limabean-agar medium to get required concentration. The medium were then poured in sterilised petri-dishes and allowed to solidify. After solidification the dishes were inoculated with a 5 mm disc cut from 7 days old pure culture of race 4 of P. infestans. Three replications were kept for each treatment along with control where no fungicide was added. The Petri-dishes were incubated at 20°C ± 1°C. After 7 days, the linear growth of the colony was measured in two directions at right angle to each other and the mean was calculated. Inhibition
of growth of each treatment was calculated by the Method
adopted by Shukla et al. (1972).

\[ I = \frac{10(C-T)}{C} \]

where, 
\[ I = \text{Inhibition} \]
\[ C = \text{Rate of growth in control (mm/24 h)} \]
\[ T = \text{Rate of growth in treated (mm/24 h)} \]

Results obtained were statistically analysed and shown
in Analysis of variance Table XXXVII.

**Fungicides**: Three non systemic fungicides namely, Bordeaux mixture (5:5:50), Burgandy mixture (5:6½:50) and Dithane
M-45 (80% Manganese ethylene bisdithiocarbamate + Zinc) and
two systemic fungicides namely Ridomil Zm 280 FW (metalaxyl +
Ziram) and Benomyl (Methyl - 1(butyl carbamoyl)-2-benzimidazo-
le carbamate) were used both in the laboratory as well as fie-
ld trials.

**In vivo tests**: Field trials were laid out using a ran-
donized block design with three replications during two conse-
cutive crop seasons of 1982-83 and 1983-84. The plot size was
2.13 m x 2.28 m with four rows of ten tubers planted at 22.5
cm spacing with inter row spacing of 52.5 cm (Dutt, 1967). Seed
tubers of susceptible variety Up-to-date were used in all the
experiments. The fungicides were sprayed with a hand sprayer
at the rate of 1685 lit/ha for Bordeaux and Burgandy mixture
(Dutt, 1967), 2 kg/ha for Dithane M-45 (Dutt, 1969), 5 lit/ha
for Ridomil (as recommended by Hindusthan Ciba-Geigy Ltd.,
Bombay) and at the same concentration (5 llt/ha) for Benomyl. First spraying was done when natural infection of plants started and subsequent spraying were carried out after 10, 20 and 30 days from the first spray. Control was made by spraying with distilled water. Observations on disease incidence were recorded 10 days after the last spray by counting all the healthy and diseased leaves of 30 plants at random.

Results:

In vitro studies on the efficacy of fungicides on the growth of P.infestans:

Results presented in Table LXIII and Figure 42 show that the growth of P.infestans was inhibited by all the five fungicides tested. Rate of inhibition increased with increase in concentration of fungicides. Growth of P.infestans was completely stopped at 10,000 ppm of all nonsystemic fungicides. Concentration at 10 ppm did not exhibit significant inhibition in case of the nonsystemic fungicides (5.80, 9.57 and 28.87 percent respectively with Bordeaux mixture, Burgandy mixture and Dithane M-45), while 50 percent inhibition was obtained with the systemic fungicides at 10 ppm concentration. Ridomil, when applied at 100 ppm concentration, completely inhibited growth of the fungus while 92.44 percent inhibition was found with Benomyl at 100 ppm concentration. Percentage of inhibition was much lower in case of nonsystemic fungicides at 100 ppm (24.96, 19.03 and 40.48 percent inhibition with Bordeaux mixture, Burgandy mixture and Dithane M-45 respectively).
Field studies on the efficacy of fungicides on the incidence of Phytophthora infestans:

Results presented in Table LXIV show that among non-systemic fungicides maximum control in the incidence of the disease was obtained with Bordeaux mixture in both seasons (Percentage of infection 21.22 and 12.45 respectively in 1982-83 and 1983-84) followed by Dithane M-45 (40.00 and 22.39 percent) and Burgandy mixture (48.84 and 33.88 percent infection of leaves). Among systemic fungicides, Ridomil was very effective in controlling late blight incidence (19.31 and 12.77 percent in the two seasons respectively) followed by Benomyl (25.73 and 24.29 percent infection respectively). Disease severity was maximum in the plots sprayed with distilled water (99.04 and 93.91 percent respectively in the two seasons). Rate of infection was more during the crop season of 1982-83 than 1983-84 inspite of similar treatment with fungicides in the two seasons.

Discussion:

Results on the efficacy of fungicides against control of Phytophthora infestans show that all the chemicals tested suppressed the growth of the fungus in the laboratory experiments as well as field trials. However variation have been observed in their respective degrees of effectiveness.

In vitro studies on the efficacy of the fungicides revealed that low concentration (10 ppm) of nonsystemic fungicides did not show significant inhibition of the mycelial
### Table LXIII: Percentage of mycelial inhibition of *P. infestans* by different fungicides at varying concentrations.

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Growth in control (mm/24 h)</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Bordeaux mixture</td>
<td>2.47</td>
<td>5.80</td>
</tr>
<tr>
<td>Burgandy mixture</td>
<td>2.47</td>
<td>9.57</td>
</tr>
<tr>
<td>Dithane M-45</td>
<td>2.47</td>
<td>28.87</td>
</tr>
<tr>
<td>Ridomil</td>
<td>2.47</td>
<td>51.95</td>
</tr>
<tr>
<td>Benomyl</td>
<td>2.47</td>
<td>50.06</td>
</tr>
</tbody>
</table>

Figures are av. of 3 replicates

C.D. for fungicide, at 1%: 3.3676

C.D. for concentration, at 1%: 3.3676

### Table LXIV: Results of spraying trial on the incidence of late blight disease during the crop seasons 1982-83 and 1983-84.

<table>
<thead>
<tr>
<th>Fungicides</th>
<th>Conc. (%)</th>
<th>I 22-83</th>
<th>23-84</th>
<th>II 22-83</th>
<th>23-84</th>
<th>III 22-83</th>
<th>23-84</th>
<th>IV 22-83</th>
<th>23-84</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bordeaux</td>
<td>1.0</td>
<td>673.00</td>
<td>843.00</td>
<td>530.00</td>
<td>739.33</td>
<td>143.33</td>
<td>104.00</td>
<td>21.22</td>
<td>12.45</td>
</tr>
<tr>
<td>Burgandy</td>
<td>1.0</td>
<td>711.33</td>
<td>827.33</td>
<td>406.33</td>
<td>587.00</td>
<td>305.00</td>
<td>333.66</td>
<td>48.84</td>
<td>33.38</td>
</tr>
<tr>
<td>Dithane M-45</td>
<td>0.2</td>
<td>741.66</td>
<td>900.00</td>
<td>453.66</td>
<td>697.66</td>
<td>288.00</td>
<td>202.33</td>
<td>40.00</td>
<td>22.39</td>
</tr>
<tr>
<td>Ridomil</td>
<td>0.1</td>
<td>616.33</td>
<td>782.00</td>
<td>497.66</td>
<td>618.33</td>
<td>118.66</td>
<td>100.66</td>
<td>19.31</td>
<td>12.77</td>
</tr>
<tr>
<td>Benomyl</td>
<td>0.05</td>
<td>715.00</td>
<td>837.00</td>
<td>531.66</td>
<td>664.66</td>
<td>183.33</td>
<td>172.33</td>
<td>25.73</td>
<td>24.29</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>697.33</td>
<td>810.33</td>
<td>6.66</td>
<td>50.66</td>
<td>690.66</td>
<td>759.66</td>
<td>99.04</td>
<td>93.91</td>
</tr>
</tbody>
</table>

I: Total number of leaves examined

II: Number of healthy leaves

III: Number of infected leaves

IV: Percentage of blight incidence
FIG. 42. INHIBITION OF MYCELIAL GROWTH (PERCENT) OF P. INFESTANS BY DIFFERENT FUNGICIDES AT VARYING CONCENTRATIONS. INTERACTION BETWEEN CONC. AND FUNGICIDE
### ANOVA XXXVII

Percentage of mycelial inhibition of *P. infestans* by different fungicides at varying concentration.

<table>
<thead>
<tr>
<th>Sources of Variation</th>
<th>D.F.</th>
<th>S.S.</th>
<th>M.S.S.</th>
<th>Variance Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fungicide</td>
<td>4</td>
<td>15713.18</td>
<td>3928.29</td>
<td>266.68 **</td>
</tr>
<tr>
<td>Concentration</td>
<td>4</td>
<td>88832.28</td>
<td>22208.07</td>
<td>1507.67 **</td>
</tr>
<tr>
<td>Replication</td>
<td>2</td>
<td>68.72</td>
<td>34.36</td>
<td>2.33 N.S.</td>
</tr>
<tr>
<td>Interaction:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fungicide X Concen-</td>
<td>16</td>
<td>12988.50</td>
<td>811.78</td>
<td>55.11 **</td>
</tr>
<tr>
<td>tration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>48</td>
<td>707.51</td>
<td>14.73</td>
<td>-</td>
</tr>
</tbody>
</table>
growth of the fungus. Application at the concentration of 1000 ppm of the nonsystemic fungicides shows distinct inhibition while at 10,000 ppm completely inhibited growth of the fungus. Dithane M-45 was found to be more effective than Bordeaux mixture and Burgandy mixture in the laboratory tests. Both the two systemic fungicides were found to be highly effective in inhibiting growth of the fungus at much lower concentration than the nonsystemic fungicides.

Field trials have revealed that spraying with Bordeaux mixture 4 times at 10 days intervals was highly effective in both crop seasons in comparison to Burgandy mixture and Dithane M-45. Effective control of late blight disease with Bordeaux mixture has been reported by Mehta and Singh (1953), Dutt et al. (1969, 70) and Dutt: (1962, 67) from Uttar Pradesh. Roy and Das (1968), however, reported Dithane M-45 to be highly effective for late blight in Assam. In the present investigation Dithane M-45 was found to be effective during the trials in 1983-84 (22.39 percent infection) but its effectiveness was found to be less during 1982-83. Burgandy mixture has been reported to be effective against late blight in Simla hills (Vasudeva and Azad, 1952). In the present investigation, although satisfactory reduction in the disease incidence was obtained with Burgandy mixture, considerable scorching of leaves resulted with the application of this fungicide. Similar report of leaf scorching with Burgandy mixture was given by Hutchinson (1976).

In the district of Lakhimpur, rains are frequent with
high relative humidity prevailing during the potato growing season. Under such conditions, Bordeaux mixture is known to be effective than all other fungicides (Cox and Large, 1960; Dutt, 1967). Paharia (1961) stated that Bordeaux mixture sprayings increase the rate of transpiration resulting in the reduction in yield in the plains of India. In the present investigation, however, no adverse effect of Bordeaux mixture has been noticed.

Both Ridomil and Benomyl were found to be highly effective in controlling the growth of *P. infestans* in vitro as well as in field trials. Both fungicides were highly effective in inhibiting growth of the fungus at 100 ppm concentration. Toxicity of Benomyl against fungi has earlier been reported. Melhan *et al.* (1975) reported that Benomyl was highly toxic to *Rhizoctonia solani*, *R. bataticola*, *Colletotrichum fulcatum*, *C. capsici*, *Phoma destructiva*, *Cladosporium cladosporoides*, *C. oxysporum*, *Elsinoe ampelina*, *Pestalotia theae* and *Aspergillus flavus* at 1-10 μg/ml while for *Fusarium oxysporum f. vesinfectum* and *Aspergillus niger*, it was toxic at relatively higher concentration i.e. 10 - 100 μg/ml. Saikia and Phukan (1983) reported that Benomyl could reduce disease intensity of blight of mung to the extent of 95.45 percent over unsprayed control. In the present investigation, in spraying trials with 0.1 percent Ridomil and 0.05 percent Benomyl, considerable reduction in the incidence of late blight disease was obtained, the former being more effective.
In the present investigation, variation has been observed in the incidence of blight in relation to treatment with fungicides in the two seasons. Incidence of blight was found to be higher during the crop season 1982-83 than 1983-84. The comparatively heavier rainfall during 1982-83 might have possibly washed away the fungicides making room for the fungus to grow and sporulate on the plant surface.

* * *