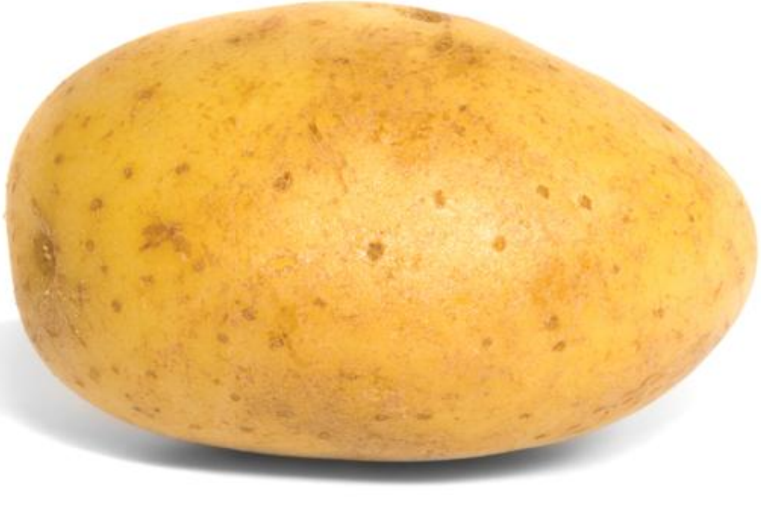
CHAPTER–I

General Introduction



GENERAL INTRODUCTION

1.1 Introduction

Potato is the world’s major non-cereal food crop and the fourth largest crop after maize, rice and wheat, with production reaching a record 325 million tonnes in 2007 (FAO, 2008). In India, the potato continues to be a remunerative crop benefiting from increasing access to irrigation and fertilizers, as well as from the continued expansion in post-harvest infrastructure viz. cold storage facilities. More than 80 percent of the potato crop is produced from the three major states of the country, Uttar Pradesh, West Bengal and Bihar in the Indo-Gangetic plains, (Singh et al., 2008). During 2015-16 the total area under potato was 23.41 thousand ha with a production of 24.47 MT (PIB, Min of Agriculture, GOI). In plains potato crop is grown in winter season (*rabi*) under assured irrigation facility from October to March. In West Bengal potato is cultivated mostly after the harvest of autumn or winter rice covering a duration of 90-100 days during November to March . The major potato growing areas are confined to the districts of Burdwan, Bankura, Paschim Medinipur, Hooghly and Howrah, constituting 65% area of the state. This is one of the most productive region wherein average yield is as high as 25.0 MT/ha in comparison to national average of 18.1 MT/ha.

The late blight disease potato has been considered to be one of the most devastating disease that could cause complete crop failure. In Gangetic plains of West Bengal there has been increased occurrence of late blight in last few decades. Late blight is caused by the oomycete pathogen *Phytophthora infestans*. Though late blight is primarily a foliar disease, it readily infects the tubers. The pathogen attacks foliage and tubers, and spread rapidly through host tissues, thereby causing a destructive necrosis. Initially the disease appears on the leaves as small water soaked lesions which grow quickly with time, coalesce and becomes necrotic resulting in browning and drying up of green foliage. Under favourable temperature (18-20^{0}C) and leaf wetness, sporangiophores emerge from the stomata and release numerous airborne sporangia causing a rapid spread of the disease and the infection is visible within 3 days. Late blight is believed to be a ‘weather-driven’ disease, dependent on two major climatic factors viz. moisture and temperature. Late blight epidemics are favoured by stable atmosphere with high moisture and moderate temperatures for several days (Harrison 1992). Unfavourable conditions may delay or temporarily interrupt the disease cycle initiation. However, besides weather variables certain agronomic practices such as planting geometry, irrigation management, nutrient management, type of cultivar as well as crop rotation also contribute to the potential risk of the disease (Zhang et al., 2004).

These climatic factors determine the mode of sporangial germination, the establishment of parasitic interaction with the host by the pathogen and the successive growing rate of pathogen through the host tissue (Becktell et al., 2005). In general climatic conditions influence primary infection, the time period from inoculation to appearance of lesions and the production of sporangia. Although not universal, the favourable conditions for disease development are minimum 2 to 3 hours of leaf wetness at the optimum temperature of 20^0C for consecutive 3 days or more (Crosier, 1934). The transition between direct and indirect germination of sporangia take place at the average temperature of 15^0C (Harrison, 1992; Judelson and Blanco, 2005) whereas indirect infection via zoospores occurs below this temperature and direct infection being most common above this temperature. The incubation period is shortest between 20^0C to 28^0C (Andrade-Piedra et al., 2005, Mizubuti et al., 1998) and the most impetuous sporangium production happens at approximately 21^0C (Crosier, 1934). For maximum spores production the most favourable temperature ranges from 15^0C to 21^0C (Andrade-Piedra et al., 2005, Mizubuti et al., 1998, Crosier, 1934).

In potato growing areas during off season pathogen may survive in soil as well as in other susceptible hosts. The basic sources of infections are mainly the infected seed tubers, cull piles, neighbouring potato fields and other host plants. The sporangia spores are washed out from the infected leaves, get into the soil and infect the tubers through lenticels and wounds. When the tubers are not well covered by hilling, infection may be possible if the tubers are contacted with infected foliage before harvesting. In very few cases late blight infected tubers develop sprout and the spout becomes the primary source of infection. Sometimes, infected tubers frequently found in cull piles become source of primary infection for a new crops. The infected tubers which were left behind during last season also serve as source of infection as the microbes remain is soil. In such cases other solanaceous plants serve as alternate host of *P. infestans* (Henfling, 1987).

Once the infection is visible on the foliage wind or splash-borne sporangia act as source of disease dispersal. Air borne sporangia can travel over larger distance. Wind, temperature, humidity, solar radiation etc. play major role to aerial transport of spores which can be categorized in following stages (i) spores releases from sporangia spores and escape from the potato canopy (Aylor, 1990), (ii) transport from one to another place by the favourable wind, (iii) deposition on susceptible host tissue by wet deposition and/or dry deposition where in the wet deposition increases the chances of germination and dry deposition can send back the spores to the atmosphere and transported to other new places.

In India late blight has been considered to be a major disease of potatoes (Singh 1996). Occurrence of late blight is common in northwestern hills of Himachal Pradesh, Uttarakhand, northeastern hills of Meghalaya and the south Indian hills. In the Indo-Gangetic plains comprising states of Bihar, Uttar Pradesh, Punjab and West Bengal it occurs with high severity once in 3 to 4 years and causes a huge loss in potato production (Ray et al., 2011). The late blight severity problem has been exacerbated by the introduction of new strains of *P. infestans* that are genetically more variable, aggressive, fit and resistant to fungicides than the ‘old’ strains (Anonymous, 2010) especially in Asia. The potato growers of West Bengal experienced a huge economic loss by late blight in recent past (2006-07 and 2008-09) resulting in steep escalation of potato prices. In addition to weather, farm management practices such as irrigation, selection of varieties and farming operations also contribute to the potential risk of the disease. Potato growers require timely and location-specific information for detection and monitoring of the infection for effective control of disease and ensuring productivity while reducing environmental pollution.

Keeping in view the devastation of potato late blight, several forecasting systems have been developed worldwide over the years. There are different models, simple to sophisticated ones which vary in terms of their complexities, input data requirement and ability for scheduling appropriate control measures, all of which are based upon the response of the pathogen to various environmental parameters and management practices. Most of the rule based models use the daily weather data to define the threshold condition for occurrence and severity of the disease (WMO, Anonymous, 2010). The rule based models are region specific. Since most of these models are developed in the European countries, the threshold rules are for the crop varieties that are exposed to a cooler climatic condition in the growth cycle. Besides that the rule based models usually do not consider the crop growth condition, phonological development as well as the management practices followed. The Gangetic alluvial region of West Bengal that represents the major potato growing regions of India is comprised of diverse agro-ecological zones. Thus the rule based models are not able to predict the disease severity very efficiently due to inherent heterogeneity of growing conditions and management practices in these regions.

Traditionally, disease damage assessment is done by visual approach which is time-consuming, labour intensive, and subjective. Therefore, there is a need to develop alternate approaches that can augment or supplement traditional techniques. Modern agricultural technology demands for an automated non-destructive methods of crop disease detection over wider spatial scale in near real time basis to ensure food security. It is desirable that the plant disease detection tool should be rapid, specific to a particular disease and sensitive to detection at the early onset of the symptoms (López et al., 2003). The spectroscopic and imaging techniques are unique disease monitoring methods that have been used over more than two decades to detect diseases and stress due to various factors, in crops and forests. Canopy reflectance data have unique capability to detect pathogen-induced biophysical changes in the plant leaf and canopy. Different disease symptoms affect the optical properties of plants in the following spectral regions: pathogen propagules in the VIS (depending on the pathogen); chlorophyll degradation (necrotic or chlorotic lesions) in the VIS and red-edge (550 nm; 650–720 nm); photosynthetic disturbance as fluorescence (450–550 nm; 690–740 nm) and in the TIR (8000–14000 nm); senescence in the VIS and NIR (680–800 nm) and also in the SWIR (1400–1600 nm and 1900–2100 nm) due to dryness; changes in canopy density and leaf area in the NIR; and changes in the transpiration rate in the TIR (8000–14000 nm). Ground distortion, colour changes in foliage, defoliation and textural differences cause variation in the spectral reflectance and aids in the identification of affected crops from the normal plants. The presence of disease in crops can alter its reflectance properties. When crop plants are stressed, such as by disease, their absorption of incident light changes in the visible range and NIR region (Carter and Knapp, 2001; Adams et al., 1999; Dawson and Curran, 1998; Lichtenthaler et al., 1996; Gitelson and Merzlyak, 1994; Guenther, 1990). Diseased potato crops usually exhibit discrete lesions on leaves, corresponding to necrotic or chlorotic regions, which increases reflectance in the VIS range, especially in the chlorophyll absorption bands. In particular, reflectance changes at wavelengths around 670 nm causes the red edge (the sharp transition in the reflectance spectrum from low red reflectance to high NIR reflectance that generally occurs around 730 nm) to shift to shorter wavelengths.

Remote sensing technology is a powerful tool to collect spectral profile of crop canopy through different spectral bands that can be used to analyze the temporal and spatial properties of the biological features of the crop, including the symptoms of late blight. Hyperspectral Remote Sensing, a technique that utilizes sensors operating in hundreds of narrow contiguous spectral bands that offers potential to improve the assessment of crop diseases. These sensors can provide quality images with high spatial and spectral resolutions required for precision agriculture (Taranik et al., 1993; Fraser, 1998; Wilson and Felt, 1998; Bianchi et al., 1999).

The early stage diagnosis of late blight disease is an important step in checking disease severity as well as their spatial dispersion using the effective fungicide spray program. There is the need for an operational disease monitoring system whereby information from all possible ground and satellite based sources are acquired and analyzed holistically on a common platform towards information dissemination and outreach to the stakeholders. Effective implementation of a Disease Monitoring System can reduce the cost of production and ensure environmental safety by judicious use of pesticides.

1.2 Aims and Objectives of the Study

The present studies were aimed to investigate the following objectives:

1. To delineate of potato growing areas with respect to crop phonological development.
2. To study of spectral characteristics of healthy potato canopy and the changes in spectral reflectance pattern with infection and severity of potato late blight disease using hyperspectral observation.
3. To establish a relationship between hyperspectral indices and potato late blight disease severity for remote monitoring.
4. To evaluate the utility of multispectral vegetation indices to distinguish the disease affected potato crops from the healthy ones and potato late blight risk mapping.
5. Development of potato late blight disease monitoring method using multispectral remote sensing data and mapping of disease severity.

1.3 Outline of the Thesis

The thesis consists of total eight chapters. Chapter one describes the background, research aim, objectives and the research approach. The second chapter describes the literature review of previous work related to this study. Chapter three describes the detail description of the study area. Chapter four gives detail about delineations of potato growing areas with respect to crop phonological development. Hyperspectral observations of diseased and healthy potato foliage are discussed in chapter five. In chapter six, modelling of potato late blight disease monitoring has been carried out using multi-temporal satellite data. The last chapter, chapter seven summarizes the study with conclusion and recommendations for future research. The short descriptions of those chapters are in the following:

Chapter 1

In chapter one the general introduction of potato late blight disease and its importance in India and West Bengal is given. The introductory chapter highlights the aim and objectives of the present study. A brief outline about the organization of the thesis has been discussed at its end.

Chapter 2

This chapter describes a comprehensive review of potato late blight disease as well as the use of Information Communication Technology (ICT) to monitor the disease epidemics. The review topics covered economic importance of disease, disease epidemics, disease cycle and environmental factors influencing potato late blight. A detail review is also done on disease monitoring and management as well as the use of space technology for disease identification and progress for developing proper late blight monitoring system.

Chapter 3

Chapter three describes the detail description about the study area. It includes geographic description, climate, physiography and soils with flora fauna and the agricultural practices. Demographic profile is also included for reference.

Chapter 4

In chapter four, the basic potato phonological profile with their phenological metrices are described. The spatial distribution of potato based cropping systems in relation to vegetation indices and modelled potato crop canopy fraction is discussed in this section.

Chapter 5

Ground based hyperspectral observation of canopy level is analyzed in this chapter to differentiate the late blight disease affected potato crops from healthy one with respect to different degree of severity. Several spectral derivatives sensitive to plant stress is constructed to establish correlation with disease severity and spectral variables.

Chapter 6

This chapter evaluates the efficiency of multi-temporal NDVI, NDWI and shortwave angle based indices derived from AWiFS data in identifying canopy pigment and moisture anomaly caused by potato late blight disease and distinguish the disease affected potato crops from the healthy ones by optimally using remote sensing based indices and mapping of late blight affected areas. A method is also developed for potato late blight disease monitoring towards exploring the disease detection potential for application of multispectral remote sensing and mapping of potato late blight disease intensity in spatial scale.

Chapter 7

This chapter summerized the major findings of the investigation and made logical conclusion of the present study. This chapter also focussed on the recommendations for future research to develop the model framework.