PREVALENCE OF SEED POTATO DISEASES IN DIFFERENT VARIETIES AVAILABLE IN MUNSHIGANJ DISTRICT OF BANGLADESH

GOLAM SHAROWAR

DEPARTMENT OF PLANT PATHOLOGY

FACULTY OF AGRICULTURE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER, 2021

PREVALENCE OF SEED POTATO DISEASES IN DIFFERENT VARIETIES AVAILABLE IN MUNSHIGANJ DISTRICT OF BANGLADESH

BY

GOLAM SHAROWAR

REGISTRATION NO. 19-10293

A Thesis
Submitted to the faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the Degree of

MASTER OF SCIENCE
IN
PLANT PATHOLOGY

SEMESTER: July-December, 2021

Approved by:

----------	**----------**
Prof. Dr. M. Salahuddin M. Chowdhury	**Prof. Dr. F.M. Aminuzzaman**
Supervisor	**Co-Supervisor**
Department of Plant Pathology	**Department of Plant Pathology**
Sher-e-Bangla Agricultural University	**Sher-e-Bangla Agricultural University**

Prof. Abu Noman Faruq Ahmmed
Chairman
Examination Committee
Department of Plant Pathology
Sher-e-Bangla Agricultural University

Department of Plant Pathology *PABX: +88029144270-9*
Sher-e-Bangla Agricultural University *Fax: +88029112649*
Sher-e-Bangla Nagar, Dhaka-1207 *Web site: www.sau.edu.bd*

CERTIFICATE

This is to certify that the thesis entitled, **"PREVALENCE OF SEED POTATO DISEASES IN DIFFERENT VARIETIES AVAILABLE IN MUNSHIGANJ DISTRICT OF BANGLADESH"** *submitted to the Department of Plant Pathology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirement for the degree of* **MASTER OF SCIENCE IN PLANT PATHOLOGY** *embodies the results of a piece of bona fide research work carried out by bearing Registration No.* **19-10293** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma, elsewhere in the country or abroad.*

I further certify that such help or sources of information, as have been availed of during the course of this investigation has duly been acknowledged.

Prof. Dr. M. Salahuddin M. Chowdhury
Department of Plant Pathology
Sher-e-Bangla Agricultural University
Dhaka- 1207
Supervisor

Dated:
Place: Dhaka, Bangladesh

Dedicated
to
My Beloved Parents and Supervisor

ACKNOWLEDGEMENTS

All praises to Almighty ALLAH who kindly enabled the author to complete the research work and prepare this thesis successfully.

The author humbly takes this opportunity to place his deep sense of gratitude to his supervisor ***Prof. Dr. M. Salahuddin M. Chowdhury****, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic guidance, valuable suggestions, constant encouragement, affection, immeasurable help and constructive criticism during the entire period of research work and preparation of the thesis.*

The author equally and deeply indebted to his co-supervisor, ***Prof. Dr. F.M. Aminuzzaman****, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, for his kind co-operation, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.*

The author would like to express his gratefulness to the Chairman, ***Prof. Abu Noman Faruq Ahmmed*** *and other respected teachers,* ***Prof. Dr. Md. Rafiqul Islam****,* ***Prof. Dr. Md. Belal Hossain, Prof. Dr. Fatema Begum****,* ***Prof. Dr. Nazneen Sultana****, and* ***Prof. Dr. Khadija Akhter*** *Department of Plant Pathology, Faculty of Agriculture, Sher-e–Bangla Agricultural University, for their valuable suggestion, direct and indirect advice, encouragement and co-operation during the whole period of the study.*

The author would like to thank the office staff of the Department of Plant Pathology and the Gowalkhali village farmer ***Mr. Nazrul Islam*** *and others for their cooperation and help to complete this research work.*

The author recalls his beloved elder brother ***Md. Tasrif Rahman Trafder, Md. Ali Haidar*** *and friends* ***Azwad Razeen, Rifat Ara Sultana, Atkiya Rahman Mithi, Shamim Reza, Md. Tohidur Rahman, Md. Towfiqur Rahman*** *and* ***Md. Moudud Ahmod*** *for their great support, help and encouragement to complete this study with pleasure.*

The author deeply expresses his heartfelt respect and gratitude to his beloved father and mother whose everlasting love, unfading faith, continuous inspiration, well wishes and blessings kept him enthusiastic throughout his life and molded him to the current position without which this work could not be completed.

The author

PREVALENCE OF SEED POTATO DISEASES IN DIFFERENT VARIETIES AVAILABLE IN MUNSHIGANJ DISTRICT OF BANGLADESH

ABSTRACT

Diseases prevalence of 19 different seed potato varieties were assessed in farmer's production land located in Munshiganj district of Bangladesh and laboratory works were conducted in the central laboratory during October 2020 to March 2021. The tested 19 varieties were collected from BADC and those were Prada, BARI Alu-40, Santana, BARI Alu-79, Innovator, Aluity, Diamant, Carollas, BARI Alu-41, BARI alu-35, BARI alu-37, Queen Anne, Granola, Asterix, Labella, Sunshine, Cardinal, Sagita, and Alkender. Data were collected on disease incidence, disease severity, plant growth, and yield contributing characteristics. Four significant diseases namely, early blight, late blight, *PLRV* and scab were identified. Causal agent *Alternaria solani* and *Phytophthora infestanc* were isolated from early blight and late blight infected leaves respectively. The highest early blight incidence (75%) was recorded in BARI Alu-79, Diamant and Santana, and the lowest incidence (55%) was recorded in Asterix and Sunshine after 75 DAS. The maximum severity (39%) was observed in Aluity and Prada while the lowest (24%) was observed in BARI Alu-40. The highest disease incidence (71.67%) of late blight was recorded in cardinal and Asterix while incidence was minimum (48.33%) in BARI Alu-41 and BARI Alu-79. The maximum severity (32.67%) was in Cardinal and the minimum (22.33%) was observed in BARI Alu-40. In *PLRV*, the highest incidence (85%) was in Labella and the lowest (23.33%) was in BARI Alu-79. The severity was the highest (34.33%) in Sagita with Labella and lowest (11%) was in BARI Alu-79. In common scab, the highest incidence (35.48%) and severity (17.85%) was observed in Diamant. However, the lowest incidence (5.52%) and severity (1.38%) were formed in Prada and Carollas variety. The highest frequency of grade C (<28mm) tuber (53.79%) was produced by Cardinal, B2 (28-44mm) tuber (57.78%) by BARI Alu-79, B1 (45-55mm) tuber (60.17%) by Innovator and A (>55mm) tuber (5.81%) by Aluity and BARI Alu-79. The counted number of tubers hill^{-1} was maximum (18.17%) in Cardinal and the lowest (5.63%) in Carollas followed by Aluity (5.74%), Prada (6.11%). The maximum weight (785.6 g) of tubers per hill was found to be in BARI Alu-40 followed by Sunshine (759.87 g). The lowest weight (287.05g) of tubers hill^{-1} was observed in BARI Alu-79 followed by Diamant (384.14g). Most significantly, BARI Alu-40 was found free of *PLRV* and scab while being less susceptible to early blight and late blight. This variety had greater tuber hill^{-1} count, high proportion of medium-sized tubers, produced maximum yield and better percentage of marketable seed tubers.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATION AND ACRONYMS

SAU	Sher-e-Bangla Agricultural University
BBS	Bangladesh Bureau of Statistics
WHO	World Health Organization
FAO	Food and Agricultural Organization
MS	Master of Science
RCBD	Randomized complete block design
et al.,	And others
Viz.,	Namely
e.g.,	exempli gratia (L), for example
Etc.,	Etcetera
i.e.,	id est (L), that is
%	Percentage
°C	Degree Celsius
mg	Milligram
l	Liter
cm	Centimeter
ml	Milliliter
g	Gram (s)
Kg	Kilogram (s)
LSD	Least Significant Difference
No.	Number
PDA	Potato Dextrose Agar

CHAPTER I
INTRODUCTION

Potato (*Solanum tuberosum* L.) known as *Alu* is an edible tuber yielding crop of the family Solanaceae. The potato crop is an annual herbaceous plant, typically propagated by planting tuber pieces that contain two or three eyes. Potato is popularly known as "The King of Vegetables" (Johora *et al*., 2017). The origin of potato is mountainous regions of South America and then it spreads out to other countries of the world (Beukema and Eanderzaag, 1990). It is the 4th important crop after wheat, rice and maize in the world and Bangladesh is the 7th producer in the world producing more than 98 lakh tons of potato (BBS, 2021). This crop considers one of the most important vegetables either for local consumption or exportation (Gado, 2013). It is part of the food plan of half one thousand million clients in the developing international locations. Potato is an important and leading food crop in Bangladesh. Potato is a highly nutritious and industrial crop which is cultivated worldwide on large scales (Pu *et al.*, 2018). It is having high nutritive value containing water (78 %), starch (18 %), protein (2%), vitamins (1%) and several trace elements (Hasse, 2008). Potato is also rich in vitamin C and B, minerals, and amino acids (leucine, tryptophan, and isoleucine) (Pandey, 2007). It is nutritionally considered a super vegetable as well as a versatile food item and it produces more carbohydrates per unit amount than either rice or wheat (Zinnat *et al.,* 2018). With comparison to cereals, potatoes have more protein, minerals, and dry matter per unit area. Some basic nutrients provided by the potato include minerals, dietary fiber, carbohydrates, and several minerals (Kadiri *et al.,* 2021).

One of the major problems faced by developing countries in general and Bangladesh in particular, is the ever-increasing population. In order to increase agricultural production further, the only option is to grow high productivity crops, like potato (Azimuddin *et al.,* 2019). It is grown not only for food, but also for animal feed, industrial uses, and seed tuber production.

The major potato growing areas of Bangladesh are Munshigonj, Jamalpur, Nilphamari, Jessore, Bogra, Pabna, Rangpur and Panchagorh. It contributes alone

as much as 54% of the total annual vegetable production of Bangladesh (BBS, 2015). The area of potato production is still in increasing from 4.61 to 4.68 lakh hectares in Bangladesh (BBS, 2021). Average yield rate of potato has been estimated 21.096 metric ton per hectare (BBS, 2021). In 2016, the country produced 9.47 million tons of potatoes contributes 55% of the total vegetable production in Bangladesh. This increase of potato production is due to its easy production in various climatic conditions (Gupta *et al*., 2015). In Bangladesh, the increase in production of potato is also due to its high yield per unit area 16,540 kg/ha in potato, 3,600 kg/ha in rice and 2,400 kg/ha in wheat. (Ahmed *et al.*, 1974).

Despite the increase in production, the yield of potatoes in Bangladesh is still lower than that in other countries. One of the reasons causing this low yield of potato in Bangladesh is the use of low yielding varieties, the low resistance of these varieties to insects and diseases, and the lack of availability of quality seed tubers (Hossain *et al.,* 2009). Seed potato production system is important. Healthy seed systems have been described as providing access to quality planting material, at the time needed, at a fair price, to all who need it (Sperling 2008). Access to quality seed is widely considered one of the main requirements for bridging large yields gaps for potato still found in most low-income countries (Schulte-Geldermann *et al.,* 2013). Healthy seed systems also act as to reduce risk of disease outbreaks by keeping spread of a disease in check or even as part of a pest eradication plan. Conversely, seed systems without effective quality control can be very efficient at spreading seed-borne pathogens. Seed systems are also important for the diffusion of new varieties with beneficial traits and the maintenance of crop diversity in the landscape. Tuber Crop research Centre (TCRC), BARI has developed a good number of potato varieties which are supposed to be higher yielder and less susceptible to insect pest and diseases. These newly varieties need to be evaluated for their performance against different diseases. Potato diseases are caused by different groups of pathogenic microorganisms. Twenty-nine fungal, thirty-nine viral, seven bacterial and six nematode, thirteen physiological disorder, three phytoplasmic diseases have been recorded in potato. In Bangladesh potato suffer

from various post-harvest diseases, but very few record are available of it. Early blight disease caused by *Alternaria solani* is one of the major diseases which causes heavy losses in the cultivation of potato crop. It is estimated that it can cause up to a 40 percent yield loss in India (Bansode *et al.*, 2018). In Bangladesh, annual potato losses due to late blight have been estimated at 25-27% (Ali and Dey, 1994). It is among the most common diseases of the potato crops in places where it is cultivated under irrigated conditions, especially when there are alternating dry and humid conditions with high temperature (Van der Waals *et al.*, 2003; Leiminger and Hausladen, 2012). Others most common destructive diseases are late blight, *PLRV* and scab of tubers. These diseases are needed to be assessed against popular seed potato varieties to obtain insight about disease incidence, severity, and performance of these varieties under the diseased condition. The overall goal of disease prevalence provides reliable estimates of the amount of disease in an area (plot, field, farm, county, region etc.) based upon the evaluation of specific symptoms and signs which are known to be characteristics for a disease, at the lowest reasonable cost with known confidence. An examination of the key components of this target goal is instructive in developing and evaluating disease assessment schemes. (Campbell *et al.*, 1994)

Therefore, considering the above facts and points this research work was designed to achieve the following objectives:

Objectives:

1. To evaluate the disease incidence and severity of major diseases in seed potato production, and
2. To assess the growth and yield performance of seed potato under farmer's field conditions.

CHAPTER II
REVIEW OF LITERATURE

Plant diseases results from the interaction of a plant pathogen, a susceptible host, and environmental factors such as climate and weather, soil conditions (temperature, pH, and moisture) and soil microbial communities (Wanner *et al.*, 2014). Plants face a broad number of abiotic and biotic stresses in their whole life span. Potato crop also confronts to these challenges as there are records of more than 300 pests and diseases which cause damage to the crop (Horton and Anderson, 1992). It is reported that there are hundreds of fungal, bacterial and mycoplasma disease attacks on potato crop affecting the tubers and foliage which makes the crop more vulnerable to other diseases (Hide and Lapwood, 1992). Damage due to the fungal and bacterial diseases may lead to an annual loss of hundreds of million dollars. Worldwide, significance of yield losses due to the diseases varies with the location and production technologies (Struik and Wiersema, 1999).

Potato (*Solanum tuberosum* L.) is an edible tuber yielding plant crop grown all over the world. This crop suffers from many diseases, among which early blight (*Alternaria solani*) of potato, late blight (*Phytophthora infestans*) of potato, Potato leaf roll virus (*PLRV*) of potato, common scab of potato is the most serious disease that cause considerable yield loss in many potato growing areas. In this chapter, an attempt has been made to review the work done on various aspects like isolation, identification, proving pathogenicity of diseases of potato by various plant extracts with different headings and sub-headings.

2.1.1 Symptoms of Early Blight

Some researchers were the first to describe the symptoms on dying potato leaves. The most susceptible plants that are physiologically old, weak, malnourished and wounded by wind, sand, hail, or insects are affected (Rands 1917a; Heuberger and Dimond 1941).

Rowe *et al*. (2021) reported that the first symptoms appear on older leaves consisting small, irregular, dark brown to black, dead spots that range from a

pinpoint to 1/2 inch in diameter in size. As the spots continues enlarging, concentric rings may form due to irregular growth patterns by the organism in the leaf tissue. This gives the lesion a characteristic “target-spot” or “bull’s eye” appearance.

A. K. Chaudhary *et al.* (2021) reported that initial lesions on young, fully expanded leaves are often confused with brown spot lesions. These first lesions appear about two to three days after infection, with further sporulation on the surface of these lesions occurring three to five days later. Early blight lesions can be diagnosed in the field easily due to the dark concentric rings alternating with bands of light-tan tissue, giving them a distinctive target spot appearance. Lesions appear as small spots-dry and papery in texture in initial condition and become brownish black and circular as they progress.

Sikora *et al.* (2004) showed that older lesions often appear angular in appearance as their margins become limited by leaf veins. Enlarging lesions are often surrounded by a narrow chlorotic halo due to toxins produced by the pathogen, which move ahead into uninfected epidermal cells.

Rands *et al*. (1917) reported that lesions are usually oval in shape, but under unfavourable conditions may remain small and angular, conforming to the interveinal spaces. Lesions enlarge, coalesce, and eventually cause death of the leaf.

Schultz and French *et al.* (2009) reported that infected stems are characterized by sunken, elongated spots that may also display the typical concentric rings. Lesions in infected tubers appear as slightly sunken dark irregular spots with raised borders; a dry rot develops internally under the skin.

Rowe *et al.* (2021) revealed that internally, the tissue imparts a brown to black corky, dry rot, usually not more than 1/4 to 3/8 inch deep. Deep cracks may form in older lesions. Tuber infection is uncommon under Ohio conditions.

2.1.2 Pathogen of early blight

Ellis and Gibson *et al.* (1975) reported that A. *solani* is classified in the domain Eukaryota, kingdom Fungi, phylum Deuteromycota, class Hyphomycetes, order Hyphales, series Porosporae. Colony morphology of *A. solani* varies widely, but is generally effuse, grayish brown to black, with a cotton-felt-or velvet-like texture

(Ellis and Gibson *et al.* 1975). Early blight is caused by the fungus*, Alternaria solani,* which universally survives in infected leaf or stem tissues on or in the soil where they are grown. Spores form on infested plant debris at the soil surface or on active lesions over an alternating wet and dry conditions which are easily carried by air currents, windblown soil, splashing rain, and irrigation water occurring mainly in warm, humid weather with heavy dews or rain. Early blight can develop quite rapidly in mid to late season and is more severe when plants are stressed by poor nutrition, drought, or other pests. Infection of potato tubers occurs through natural openings or injuries in the skin. Tubers may come in contact with spores during harvest and lesions may continue to develop in storage (Schultz and French, 2009).

King and Alexander *et al.* (1969) revealed that cells of *A. solani* are multinucleate, but different organs vary in the number of nuclei. Nuclear division in hyphal cells is followed by multiple septation, which results in the division of elongated tip cells into several multinucleate cells. The fungus produces dark to black conidia (asexual spores). This fungus has not been found to produce sexual spores. (Schultz and French, 2009). *Alternaria* spp. have dark-colored mycelium, and in older diseased tissue they produce short, simple, erect conidiophores that bear single or branched chains of conidia. Conidia possess large, dark, long, or pear shaped and multicellular, with both transverse and longitudinal cross wall's structure which are detached easily and are carried by air currents (Agrios, 2005).

A. K. Chaudhary *et al.* (2021) reported that conidia are usually pale to olivaceous-brown, produced singly or seldom in short chains, straight or slightly flexuous, obclavate to elongate, double walled with 0–8 longitudinal or oblique and 6–19 transverse septa, 75–350 µm in length and 20–30 µm in diameter in the broadest part (Ellis and Martin 1882; Rao 1964, 1969). Beaks are about half to double the length of the conidium, filiform, septate, hyaline to pale brown and 5–9 µm in diameter (Ellis and Martin 1882; Rao 1964, 1969).

Neergaard *et al.* (1945) showed that because of the variability in spore dimensions, they overlap with dimensions of other large spore *Alternaria* species. In routine work, identification is assisted by leaf symptoms, host range and cultural

characteristics. Biochemical or molecular techniques best verify the identity of the fungus. Conidiophores are dark or olivaceous brown, thick-walled, straight to flexuous, septate, arise singly or in small groups, up to 110 µm in length and 6–10µm in diameter (Ellis and Gibson, 1975). Conidiogenesis is tretic (Neergaard 1945; Ellis and Gibson 1975).

A. K. Chaudhary *et al.* (2021) reported that most of the species of *Alternaria* are mostly saprophytic i.e., they cannot infect living plant tissues but grow only on dead or decaying plant tissue generally on senescent or old tissues such as old petals, old leaves, and ripe fruit. So, it is mostly difficult to decide whether an *Alternaria* fungus found on diseased tissue is the cause of the disease or a secondary contaminant. Many species of *Alternaria* produce toxins. (Agrios, 2005).

2.2.1 Symptoms of late blight

Late blight may cause total destruction of all plants in a field within a week or two when weather is cool and wet (Hooker *et al.,* 1981; Frey *et al.,* 1993; Van der Zaag *et al.,* 1996; Agrios *et al.*, 2005). The disease is also very distractive to tomatoes and some other members of the family solanaceae. Late blight may kill the foliage and stems of potato and tomato plants at any time during the growing season. It also attacks potato tubers and tomato fruits in the field, which rot either in the field or while in storage (Agrios *et al.*, 2005). It attacks the leaves, stems, and tubers of potato plants (Mercure *et al.*, 1998).

RK Arora *et al.* (2014) reported that the disease appears as water-soaked irregular pale green lesions mostly near tip and margins of leaves which rapidly grow into large brown to purplish black necrotic spots. A white mildew, which consists of sporangia and spores of the pathogen, can be seen on lower surface of the infected leaves especially around the edges of the necrotic lesions. Light to dark brown lesions encircle the stems. The affected stems and petioles become weak at such locations and may collapse. Entire crop gives blackened blighted appearance especially under disease favourable conditions and may be destroyed within a week. Tubers in soil become infected by rain borne sporangia coming from the diseased foliage. Late blight infected tubers show irregular reddish brown to purplish areas

which extend into internal tissues of the tubers. The infected tubers usually are hard, dry, and firm but may get attacked by soft rot causing bacteria and rot in field and stores.

2.2.2 Pathogen of late blight

The pathogen is highly variable and adapt to the newly bred varieties and fungicides. Late blight is caused by *Phytophthora infestans* (Mont.) de Bary.

Adl *et al*. (2005) reported that it belongs to the oomycetes, a diverse group of eukaryotic microorganisms in a group called the Stramenopiles, clustering together with others in a super group, the Chromalveaolata.

Baldauf *et al*. (2000) reported that the position of the oomycetes as a unique lineage of eukaryotes unrelated to true fungi but closely related to heterokont (brown algae) and diatoms which is well established through molecular phylogenies and biochemical studies.

The causal organism of potato late blight is Phytophthora infestans (Mont.) de Bary. The genus Phytophthora belongs to the Oomycetes, which are unrelated to true fungi (Shaw and Khaki, 1971). The genus Phytophthora contains some species (including P. infestans) that are heterothallic (Frey *et al.,* 1993)

Fry *et al.* (2008) reported that region wise economic importance of late blight shows that the disease takes highest toll of potato in Sub-Saharan Africa (44% crop losses) followed by South-East Asia (35%). Information on various aspects of late blight has been reviewed by different workers (Cooke *et al.,* 2011; Monjil *et al.,* 2015).

Singh *et al.,* (2000) reported that timely forecasting of the disease may result in lesser application of fungicides with effective management of the disease. Due to differences in prevailing weather conditions, its severity varies from region to region. Temperature, relative humidity (%) and precipitation are the key input parameters for developing forecast model.

In Bangladesh, many researchers were worked on climatic variability on major crops and adaptation in agriculture, impact of wind speed, temperature extreme, precipitation on major crop cultivation etc. rather than the link of disease infestation

with environmental factors (Rokonuzzaman *et al.*, 2018; Rahman *et al.*, 2019; Haque *et al.,* 2019; Afrin *et al.*, 2018).

The mycelium produces branched sporangiophores that produce lemon-shaped sporangia at their tips. At the places where sporangia are produced; the sporangiophores form swellings that are characteristic for these fungi (Agrios *et al.*, 2005). *P. infestans* is the best known, most studied, and still among the destructive of all potato diseases of the species of phytophthora.

2.3.1 Symptoms of common scab disease

Common scab of potato produces variable symptoms consistently (McKee *et al.*, 1958; Driscoll *et al.*, 2007). Common scab symptoms on potato tubers includes of corky lesions which may be superficial or immersed on tuber surface (Labruyere *et al.*, 1971; Goth *et al.*, 1995; Loria *et al.*, 1997).

Lacey *et al.* (2000) reported that disease symptoms at early stages may appear as necrosis damage at the infection site which later on progresses to corky lesions due to the deterioration of surrounding tissues of tube.

These lesions may also appear to be a russeted area which covers whole of the tuber surface or it may emerge as small loops covered with corky tissues along with a slight protuberances. (Agrios *et al.*, 2005).

Powelson, M.L. *et al.* (1993) reported that the pathogen produces generally rough, circular, corky, raised, brown colored lesions which are randomly developed across the surface of tuber, and they also vary in sizes. Occasionally these lesions also develop as water-soaked regions on tuber surface. As the time went by these lesions increase in size ranging up to 3-10 mm deep in disease infected tubers and 3-5 mm around the lenticles and they also becomes corky and coalesce in nature (Adams *et al.*, 1975; Wilson *et al.*, 2001).

Colonization of pathogens on potato tubers initiate the primary symptoms of scab supported by the necrotic symptoms at the infection site. The depth of lesions depends upon the nature of cultivar, soil conditions and pests interference (Hooker *et al.*, 1981).

Lapwood and Adams *et al.* (1975) stated that symptoms of common scab can only be detected after the harvest of crop.Common scab do not induce any visible symptoms on aerial parts of the plants however it produces symptoms only on roots and stolons of infected plants (Smith *et al.*, 1968).

2.3.2 Causal organism of common scab

Common scab of potato is induced by *Streptomyces scabies* (Leiner *et al.*, 1996; Goyer and Beaulieu, 1997; Park *et al.*, 2003). Pytopathogenic soil dwelling bacteria from the genus *Streptomyces* (Driscoll, 2007) comprising of *S. turgidiscabiei,* (Lambert and Loria, 1989; Miyajima *et al.*, 1998) *S. acidiscabiei,* (Bonde and McIntyre, 1968) *S. europseiscabiei, S. stelliscabiei, S. caviscabiei,* (Bouchek-Mechiche et al., 2000) *S. lurdiscabiei, S. niveiscabiei S. puniciscabiei* sp. nov. (Park *et al.,* 2003) is responsible for common scab and several other scab-like diseases on potato crop.

Bouchek-Mechiche *et al.* (2000) reported that the disease symptoms of those species were identical to *Streptomyces scabies*. Approximately 30 species of *Streptomyces* spp. have been reported apart from *S. scabiei.* Moreover in Tasmania plant pathogenic bacteria causing scab is described to be several strains of *Streptomyces scabies* (Wilson and Conner, 1995).

Hosny *et al.* (2014) stated that *S. scabiei* is an aerobic, saprophytic, filamentous bacterium which can survive for a couple of decades in soil and plant residues.

Lorang *et al.* (1995) reported that the bacteria comprises of branched and slender (1µm thick) mycelium (Agrios, 2005) and it belongs to gram +ve category of prokaryotic bacteria. The causal organism of common scab is widely spread (Pavlista, 1996) in soil and it also act as a seed-borne pathogen (Kobayashi *et al.*, 2005; Wang and Lazarovits, 2005).

The pathogen causes a wide number of disease symptoms on potato tubers, these symptoms are brought about by the aid of a phytotoxins called as thaxtomin which is formed by *Streptomyces* spp. (Loria *et al.*, 2006).

2.4.1 *PLRV* and its transmission

Woodford *et al.* (1994) indicated that the virus transmission by insects is a highly variable process because it involves interactions between the virus, vector and plant. In nature, *PLRV* is only transmitted by aphids. It can be transmitted by at least 11 aphid species (Kennedy et al. 1962; Kostiw *et al.*, 1980), of which the peach-potato aphid *(Myzus persicae* Sulz.) is the most efficient vector (Robert and Maury 1970; Robert 1971; Sylvester 1980). *PLRV* can be artificially transmitted by stem grafting.

Black *et al.* (1959) reported that *PLRV*, like other luteoviruses, is transmitted by aphids in a persistent manner, also referred to as a circulative one. The former term reflects the ability of the virus to remain in the infective form in the vector for a long time, usually to its death. This property is important from the point of view of virus epidemiology. The term 'circulative' refers to the circulation of the virus through the aphid. The mechanism of the virus transmission by aphids has been intensively studied since the 1930s (Smith *et al.,* 1929; Elze *et al.*, 1931; Day *et al.*, 1955; Harrison *et al.*, 1958; Ponsen *et al.,* 1980).

These studies were instrumental in the under- standing of the transport of luteoviruses through the vector's body. When ingested by the aphid, virus particles pass from the gut into the haemolymph where they can circulate through the aphid, enter the salivary glands and pass into the saliva, thereby entering a new plant when the insect feeds again. The luteovirus circulation in the vector has been studied mainly with regard to *PLRV* and BYDV (Gildow and Rochow 1980a; Gildow 1985, 1987). There are differences of opinion between authors on the site of passage of the virus particles from the gut lumen into the haemocoel.

Weidemann *et al.* (1982) reported that the whole midgut, including the stomach, could be the site of the *PLRV* passage in M. persicae, while (Garret *et al.,* 1993) found only the intestine involved in this process. Gildow *et al.*, (1985) demonstrated the hindgut as being the site for BYDV to pass into the haemocoel of Rhopalosiphum padi L.

Garret *et al.* (1993) suggested that the differences between the results obtained in these three studies could be due to the different viruses, virus strains and aphid

species or clones used. Based on ultrastructural studies on the localization of virions of BYDV strains in vector and non-vector aphids, a model of receptor-mediated endocytosis-exocytosis has been developed to describe this transcellular virus transport (Gildow *et al.*, 1987, 1993). This model assumes that a receptor- mediated attachment of the virus particles to membranes controls the luteovirus acquisition and vector specificity (Gildow *et al.*, 1987). Evidence has recently accumulated that the ability of aphids to transmit *PLRV* and BWYV and some other viruses results from the specific properties of the virus protein (Massalski and Harrison 1987; Jolly and Mayo 1993; Maiss *et al.*, 1993;) and from the interaction between specific regions of the virus protein and some proteins of the vector (Schmidt *et al.*, 1993; van den Heuvel *et al.*, 1993). It has been suggested that the major coat protein and the capsid-associated protein, expressed through readthrough of the coat protein gene termination codon, play a dominant role in this transcellular virus transport (Bahner *et al*., 1990; Vincent *et al.,* 1990; Mayo *et al.* 1993; van den Heuvel *et al.* 1993).

More recently, van den Heuvel *et al.* (1994) screened M. persicae proteins as putative *PLRV* binding molecules using a virus overlay assay of protein blots. They found that purified *PLRV* particles exhibited an affinity for five aphid proteins. The one most readily detected has been identified as a protein synthesized by bacterial endosymbionts of the aphid that are released into the haemolymph. The authors conclude that this protein symbionin plays a crucial role in determining the persistent nature of the *PLRV* in the aphid haemocoel. Since the luteovirus needs time to circulate through the aphid, there is a latent period between the virus ingestion and egestion with saliva (Tamada and Harrison, 1981). In general, the acquisition and transmission of the luteovirus can be completed within a few days.

Tanaka and Shiota *et al.* (1970) reported that the transmission threshold period of *PLRV* in M. persicae was 16-24 h at room temperature. The latent period was found to be at least 2 days shorter at 25-30 °C than at 15 °C (Tamada and Harrison, 1981). A reduction in the length of the latent period at higher temperatures could be the explanation for the higher rate of *PLRV* transmission by M. persicae following virus

acquisition at higher temperatures (usually 25-30 °C) than at lower temperatures (15-22°C) (Tamada and Harrison, 1981; Syller, 1987). An increase in the transmission of *PLRV* with an increase in temperature can also result from the greater amount of virus accumulated in aphids fed at elevated temperatures (Syller, 1994), perhaps because of the enhanced imbibition of *PLRV*- containing plant sap. The successful transmission of the luteovirus by aphids can depend on the feeding behavior of the vector during acquisition and inoculation and on the length of time the aphid feeds in the phloem (Woodford *et al*., 1994).

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site

The field experiment was carried out in a potato cultivation land at Gowalkhali village of Sirajdikhan upzilla in Munshiganj district and the research was conducted in Dr. M. A. Wazed Miah Central Research laboratory, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Sher-e Bangla Nagar, Dhaka-1207. Experimental location has been given in Figure-1.

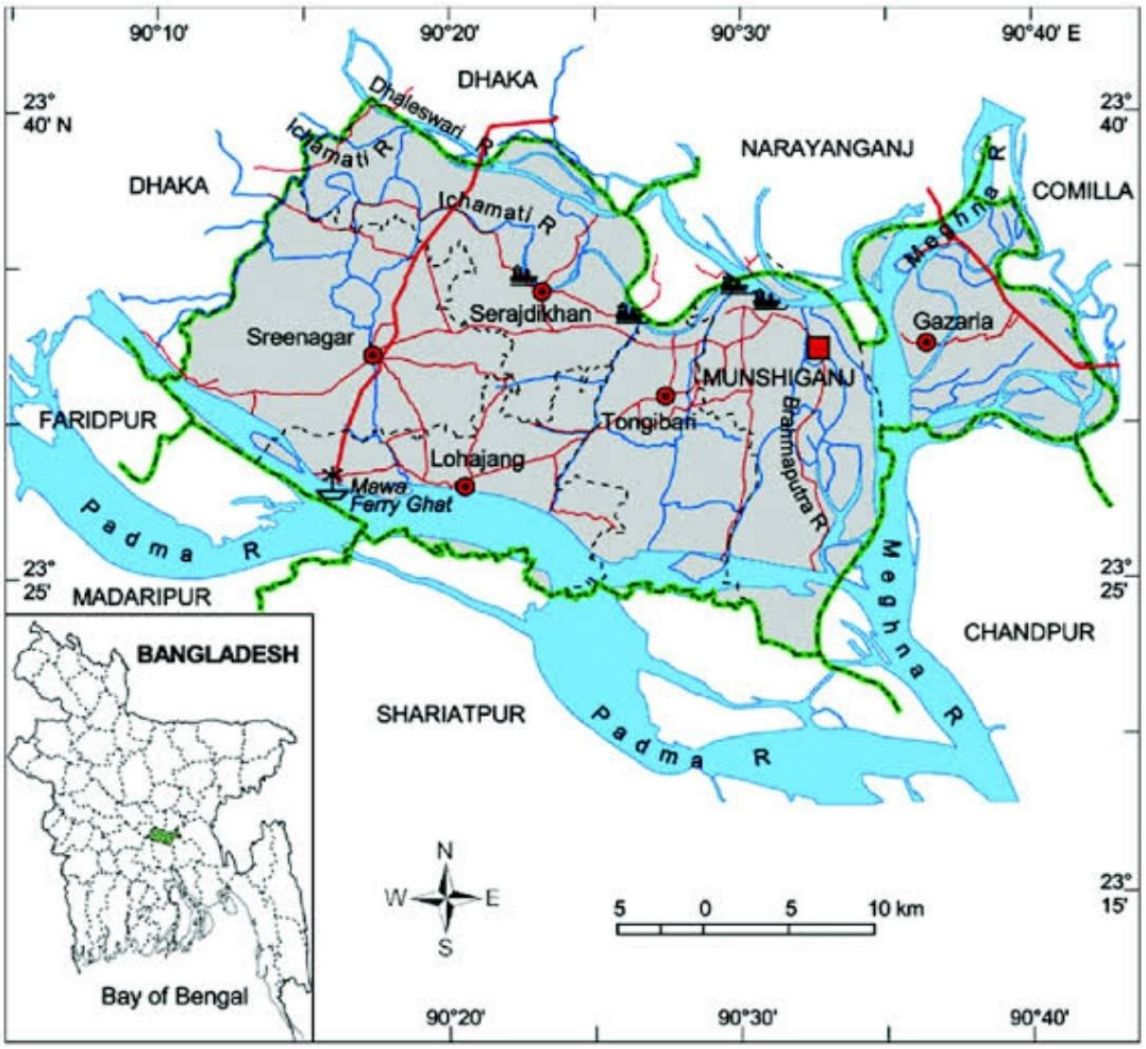


Figure 1. Experimental site in map

3.2 Period of Experiment

The field experiment was conducted during the period October 2020 to March 2021 and the laboratory research carried out during January to March 2021.

3.3 Design of the experiment

The field experiment was conducted following randomized complete block design (RCBD) with three (03) replications and nineteen (19) varieties of potatoes as treatments, therefore, a total of 57 experimental unit were taken to conduct the experiment of which treatments were randomized. The field was divided into three blocks representing the replications. The experimental unit or plot size for each variety was 5m × 2.5m, maintain a plot-to-plot distance between 0.5 meter. Each plot was divided into three blocks maintaining a block-to-block distance between of 0.5 meter. The field layout was done as per experimental design on 30th November 2019.

3.4 Potato Production

Potato crop was cultivated following agronomical cultural practices such as potato seed tuber collection, land preparation, sowing of potato seed, fertilizer application, irrigation, weeding, earthing-up etc. were done as and when necessary.

3.4.1 Variety collection

The potato seed tuber varieties were collected from cold storage of Bangladesh Agricultural Development Corporation (BADC), Munshiganj and the varieties were Prada, BARI Alu-40, Santana, BARI Alu-79, Innovator, Aluity, Diamant, Carollas, BARI Alu-41, BARI alu-35, BARI alu-37, Queen Anne, Granola, Asterix, Labella, Sunshine, Cardinal, Sagita, and Alkender.

3.4.2 Materials used in the experiment

No.	Variety	Figure	Characteristics
1.	**BARI Alu-79**		Plant medium height and average stem per plant 4/6, stem green and hard, leaf very few waves like. Potato oval to long-oval shape, medium to large size, color red, skin light unsmooth, shallow eye. Duration 85-90 days production 35-54 tha^{-1}.
2.	**BARI Alu-40**		Plant medium height and average stem per plant 4/5, stem green, leaf very few waves like. Potato petite oval to long-oval shape, medium to large size, color yellow, skin smooth, medium shallow eye. Duration 90-95 days and production 35-55 tha^{-1}.
3.	**Innovator**		Plant strong, medium height and average stem per plant, green leaves. Potato tuber oval shaped, medium to large size, skin unsmooth and light yellow in color also shallow eye. Duration 90-95 days and production 40-45 tha^{-1}.
4.	**Aluity**		Plant strong, long height and average stem per plant, green leaves. Potato tuber oval shaped, medium to large size, skin smooth and red in color also shallow eye. Duration 90-95 days and production 40-45 tha^{-1}.
5.	**BARI Alu-8 (Cardinal)**		Plant hard, rapid growing, number of stem lower but wave like. Tuber red, oval, medium size, skin smooth, flesh yellow and shallow eye. Duration 90-95 days and production 25-30 $tonha^{-1}$.

6.	**Prada**		Plant strong, green leaves, medium number of stems. Potato tuber white to yellowish, oval shaped, medium to large size, skin medium smooth and shallow eye. Duration 85-90 days andproduction 40-45 tonha^{-1}.
7.	**Sunshine**		Plant strong, long height and average stem per plant, green leaves. Potato tuber oval shaped, medium to large size, skin smooth and yellow in color also shallow eye. Duration 90-95 days and production 45-50 tonha^{-1}.
8.	**BARI Alu-7 (Diamant)**		Plant strong, rapid growing and deep green leaves. Potato tuber white, oval shaped, medium to large size, skin smooth and light yellow in color also shallow eye. Duration 90-95 days and production 25-35 tonha^{-1}.
9.	**BARI Alu-91 (Carollas)**		Plant medium height and average stem low, stem light green, leaf medium large. Potato round to flat round shape large, color reddish yellow, skin medium smooth, eye shallow. Duration 90-95 days and production 34-41 tonha$^{-1.}$
10.	**Santana**		Plant medium height and average stem per plant 4/5, stem green, leaf large. Potato round to oval round shape, large, yellow color, skin smooth, eye medium shallow. Duration: 90-95 daysand production 45-50 tonha^{-1}.
11.	**BARI Alu-41**		Plant medium height and average stem per plant 4/5, stem green, leaf large. Potato round to flat round shape large, color deep red, skin smooth, eye medium shallow. Duration 90-95 days and production 38-44 tonha^{-1}.

12. BARI alu-37

Plant medium height and average stem per plant 4/5, leaf green. Potato long-oval shape, medium size, color light brown and skin smooth, shallow eye. Duration: 90-95 days and production 30-40 tonha^{-1}.

13. BARI Alu-25 (Asterix)

Plant and average 3-4 stem/plant, leaf large, green, and bushy. Potato oval shape to all, medium to large size, skin red and smooth, shallow eye. Duration 90-95 days and production: 25-30 tonha^{-1}.

14. BARI Alu-31 (Sagita)

Plant medium height and average stem per plant 4/5, stem green. Potato oval shape large, color of potato light yellowish, skin smooth, eye shallow. Duration 90-95 days and production: 25-35 tonha^{-1}.

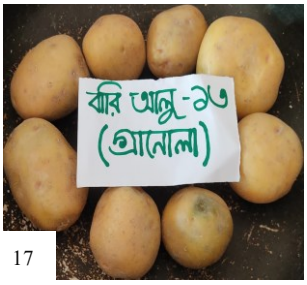
15. Labella

Plant strong, average height and stem per plant, green leaves. Potato tuber oval shaped, medium to large size, skin smooth and red in color also medium shallow eye. Duration 90-95 days and production: 45-50 tonha^{-1}.

16. BARI alu-35

Plant medium height and average number of stems 4/5, stem green leaf lower wave. Potato oval shape and medium size, color brown and skin smooth, eye shallow. Duration 90-95 days and production: 30-45 tonha^{-1}.

17. BARI Alu-13 (Granola)



Plant slightly bushy, number of stems more and green, at first plant grown slowly but letter rapid grow. Potato oval shaped medium size, skin rough, light yellow color and eye slight shallow. Duration: 85-95 days production: 25-35 tonha^{-1}.

18. Queen Anne	 18	Plant hard and average 3-4 stem/plant, leaf large, green and bushy. Potato oval shape to all, medium to large size, skin red and smooth, shallow eye. Duration 90-95 days and production: 35-40 tonha^{-1}.
19. Alkender	 19	Plant hard and strong, medium number of stem but wave like. Tuber yellow, oval, medium size to large, skin smooth, flesh yellow and shallow eye. Duration: 90-95 days and production: 35-40 tonha^{-1}.

(Azad *et al.,* 2020; Kundu *et al.,* 2013)

3.4.3 Land preparation

The experimental field was first ploughed on 20th October 2019. The land was ploughed thoroughly with a power tiller and then laddering was done to obtain a desirable tilt. The clods of the land were pulverized to make the soil into small pieces. Weeds, stubbles, and crop residues were cleaned from the land. The final ploughing and land preparation was done on 30th October 2019.

3.4.4 Fertilizer application

Before final land preparation, cow dung @ 10 t/ha was applied. The crop was fertilized with 350, 250, 270, 120, 120, 10, 6kg/ha of Urea, TSP, MP, Gypsum, Magnesium sulphate, Zinc sulphate and Borax, respectively as recommended by Tuber Crop Research Centre (Anonymous, 2005). One half of the Urea and full dose of all other fertilizers were applied prior to planting. The rest half of the Urea was applied 25 days after planting when first earthing up was done.

3.4.5 Seed tuber plantation

Selected varieties of potato seed tubers were planted maintaining 60 cm x 30 cm spacing. The experimental unit size was 5m × 2.5m. After thorough tillage operation upon application of fertilizer the land was brought to tilth by repeated

laddering. The plots and experimental unit blocks were measured and marked by making boundary. The collected healthy seed tuber potato variety from cold storage of Bangladesh Agricultural Development Corporation (BADC) which was used in the experimental field. The average weight of potato seed tuber was 50 g, and which were above 50 g were cut into two pieces. The line sowing of tuber was done maintaining a line-to-line distance of 60 cm and seed tuber to seed tuber 30 cm. Tuber seed was sowed at a depth of about 6 cm.

3.4.6 Earthing up and Furrow preparation

After 25 days of emergence seedlings first earthing up was done. Soil was dug out from in between of line and shifted at the base of the seedlings, resulted in ridge and furrow.

3.4.7 Irrigation

Irrigation was provided in the field at regular interval to meet up the water demand. Irrigation ensured at the critical stage of growing to obtain optimum tuber formation.

3.4.8 Weeding

Weeding was done at the early growth stage of the seedling to keep the field free from weeds. Weeding was done 2 times, one at 20 days of emergence and the other was at 40 days of seedling.

3.5 Harvesting of potatoes

When the plant of the potatoes was dried up and tuber attained its maximum size the initiative for harvesting was taken. Harvesting was done at about 90 days after seedling emergence. Wooden made plough was used to dug out the tubers. After collecting the tubers, the debris were removed. Potatoes were slightly sundry to reduce the moisture and grading was done to separate in different group based on size.

3.6 Data collection on plant growth

Data was collected on the growth of potato seedling based on plant height, number of tiller and number of leaves. Data was collected at 15 days of interval from 45 days to 75 days of emergence viz. at 45 days, 60 days, and 75 days of emergence. Form each experiment unit five plants were randomly sampled, and data plant height was measured using a meter scale. Tiller, leaves were also counted. Data was recorded in data book.

3.7 Data collection on disease incidence and disease severity

Disease incidence and disease severity data was calculated according to the affected plant parts as leaves and tuber into potato variety field.

3.7.1 Disease Incidence (DI) (%)

The land was divided by nineteen locations and each location was further divided into three blocks which was considered as replication. Five plants were randomly selected from four corners and center of the plot representing each site. Plant diseased samples were collected in the polythene bags from the fields and stores and brought to the laboratory for further experimental study. All the leaves were examined for recording disease incidence, and it was worked out as formula given by Raza *et al.,* (2019).

$$\text{Disease incidence (\%)} = \frac{\text{Number of disease leaves}}{\text{Total no. of leaves examined}} \times 100 \quad \ldots\ldots (1)$$

3.7.2 Disease Severity (DS) (%)

The disease severity was measured by randomly selected four plants from each block at different places in the plot field and the observation was recorded by using the disease rating scale described by Yaganza *et al.,* (2004). The disease severity was calculated using the following formula:

$$DS\ (\%) = \frac{\text{Summation of numerical rating}}{\text{No. of plants examined} \times \text{maximum disease score}} \times 100 \ldots (2)$$

3.7.3 Determination of disease incidence and disease severity scoring of early and late blight

For calculating percent disease incidence and disease severity scoring of the disease was needed. The infected foliar was scored by a scale range from 0-5 based on the severity of infection. The observation on the extent of the foliage blighted was recorded by using the disease rating scale by Mohan and Thind (1999).

The score 0 denotes healthy leaves, score 1 means that the foliar infection is less than 10%, score 2 means that the infection in between 11-25%, score 3 means that the infection was in between 26-50%, score 4 means that the infection was between 51-75%, and the last score was 5 which means that the infection was more than 75% of the leaves. (Table 1)

Table 1. Disease rating scale of early blight and late blight of potato

Scale	Severity symptoms for the whole plant assay
0	Healthy
1	About <10% of the total leaf area blighted
2	11-25% of the total leaf area blighted
3	26-50% of the total leaf area blighted
4	51-75% of the total leaf area blighted
5	>75% of the total leaf or whole plant area blighted and plant dead

3.7.4 Disease Score description in terms of *Potato Leaf Roll Virus*

The disease incidence of *PLRV* infected plants showing leaf roll symptoms were determined by visual inspection at every line. A survey of infected plants was carried out weekly starting from emergence date till the end of the season. The composite sample of each entry was collected in sample bags and brought in the laboratory for the confirmation of *PLRV*. The disease incidence and disease severity

were also recorded to find the level of resistance and susceptibility of potato varieties/lines/clones based on the following rating scale by Khan *et al.,* (2006).

Table 2. Disease rating scale of *PLRV* of potato

Score	Severity symptoms for the whole plant assay
0	No symptoms.
1	Rolling of upper leaves (Primary infection)
2	Rolling of upper and lower leaves (Secondary infection), erect growth.
3	Rolling of leaves extending, leaves become stiff and leathery, stunting of plants and erect growth
4	Short internodes, papery sound of leathery leaves, rolling and stunting of whole plants. Young buds are slight yellowish and purplish
5	Clear rolling of leaves, sever stunting, few tubers and tuber necrosis

3.7.5 Disease Score description in terms of percentage of Potato Scab

Disease incidence and severity was measured based on symptoms on the surface of tubers. Disease incidence and severity was recorded according to disease severity rating scales (Nahar *et al.,* 2013).

Table 3. Disease rating scale of scab of potato disease severity.

Score	Severity symptoms for the whole plant assay
0	No symptom
1	Very small lesions
2	Small superficial lesions
3	Periderm broken
4	Light pitted
5	Deep pitted

3.8 Pathogen identification in laboratory study

3.8.1 Isolation and Identification of *Alternaria solani*

The infected samples of potato showing symptoms of *Alternaria* leaf spot disease were collected from the experiment field. Fungal pathogen was isolated from diseased samples of potato using standard methodology on potato dextrose agar (PDA) medium. Small bits of infected portions were surface sterilized for 1 minute in mercuric chloride solution (0.1%) and washed thrice in sterilized distilled water under totally aseptic conditions in a laminar air flow. These were then dried by keeping in two folds of sterilized filter papers then aseptically transferred to PDA in Petri plates. The plates were incubated at 27±1ºC for 7-8 days. For Sub-culturing 5 mm bit of the culture were cut from the periphery of the mycelial growth of 6-7 days old colonies and transferred on to the (PDA) slants. The cultures were incubated at 27±1ºC for growth and sporulation and further purified by single spore/hyphal tip method (Plate 1).

Pure cultures were maintained on PDA slants. The microscopic examination of cultures indicated that the fungus belongs to the genus *Alternaria*. The culture was maintained at 4ºC and also by periodical transfers on PDA slants for further use.

Temporary mounts were prepared from freshly sub cultured sporulating culture on the slides in lacto phenol and cotton blue for observing the morphological characters of the fungus such as mycelium, conidiophores, conidia and various cultural characters on PDA media these slides were examined thoroughly under the microscope. The standard references of *Alternaria alternata* were used for identification (Simmons, 2007).

Plate 1. PDA media preparation, A. Potato peeling, slicing and boiling water for 15 minutes, B. Agar powder and dextrose, C. Potato extract in conical flask.

3.8.2 Isolation and Identification of *Phytophthora infestance*

The plant samples were obtained from experimental research field. Roots and stems of potato seedlings with damping off disease symptoms were washed to remove any excess peat moss. Then, the infested plant parts were surface-sterilized using 5% v/v hypochlorite for 30 seconds, washed with sterile water, and blot-dried on sterile filter paper. Plant pieces were cut into 0.5cm length before being placed on to potato dextrose agar (PDA). The pathogen *Phytophthora infestans* is a tricky pathogen to grow on PDA media as it is a slow growing fungus. Specialized media is used to grow a pure culture of *Phytophthora infestans*. But here it came out possible by decreasing the amount of dextrose in PDA media. As it is a slow growing pathogen the lessened amount of food didn't allow any other fast-growing pathogen to grow over P. infestans. And in this way after 10-15days culture was obtained from the leave pieces and in the meantime, it was taken to reculture to another similar PDA plate. The pathogenic fungi were identified based on colony morphology and by the characteristics of sporangium and oospores (Plate 1).

3.9 Vegetative growth and Potato tuber yield parameters

Twenty potato plants were randomly chosen from each replicate, for each treatment, after 45 days of sown. The effective performance of treatments on the average leaves per plant, plant height, and number of tillers per plant were calculated

following as described by Abou-Hussein *et al.,* (2002). At harvest time data on the average total potato tuber yield (g) per plant and the average tuber weight (g) at each treatment were recorded.

3.10 Statistical analysis

Data collected during experimental period were compiled and tabulated in Microsoft Excel 2013 and analyzed with Statistical package program STATISTIX 10.0. Treatment means were compared with Least Significance Difference Test (LSD). The value of LSD at the significance level of 5% was used for comparison between the data mean.

CHAPTER IV
RESULTS

The experiment was conducted to evaluate the disease intensity level of disease incidence and severity in 19 varieties of seed potato under natural field conditions where no pesticides or fungicides were used. Results found from collected data on disease symptoms, the causal agents, disease incidence and severity on different days after sowing (DAS) with plant growth and yield response have been presented in this chapter.

4.1 Early blight disease

4.1.1 Symptoms

Symptoms first appeared as small circular lesions on the leaf surface. Later these lesions were turned into dark brown or black lesions with concentric rings on leaves. Lesions were usually oval in form and underneath the leaves were small and angular within the inter venial areas (Plate 2).

4.1.2 Isolation and identification of fungus (*Alternaria solani*)

Isolation of the pathogen was made from potato leaves showing typical symptoms of the disease. The fungus was successfully isolated on potato dextrose agar medium and profuse growth were observed. In pure culture, the fungal colony was gray, brown to black in color, and it had hairy appearance. Under microscope, long beaked, muriform, dark colored conidia were observed and both longitudinal and transverse septa were observed in mature conidia (Plate 3). Based on the characters of the colony and morphological characters of conidia the fungus was identified as *Alternaria solani.*

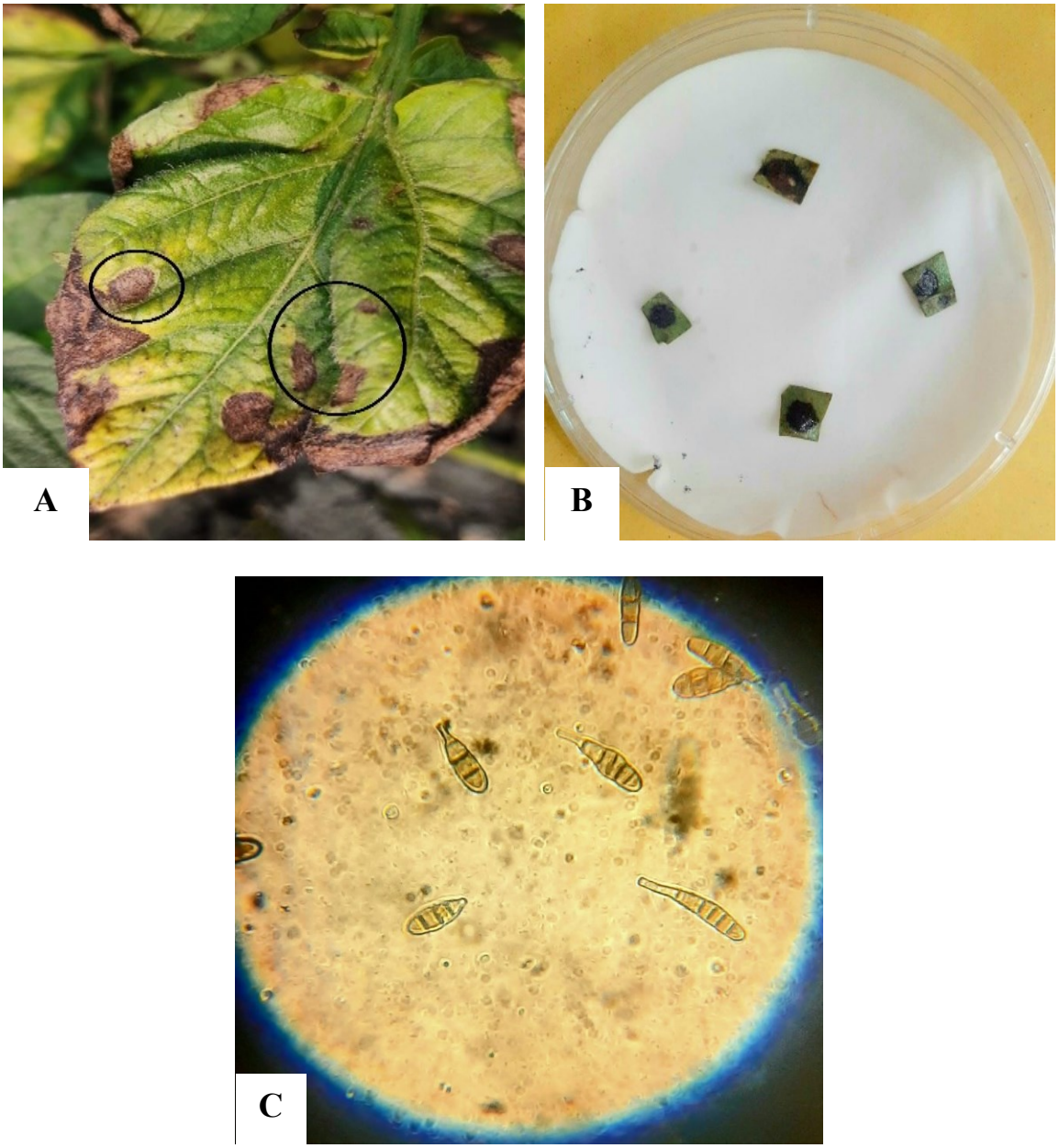


Plate 2. Early blight symptoms, isolation and identification of fungus, A. Symptom first appeared as small brown color spots with concentric rings; B. Pathogen growing on PDA media; C. Compound microscopic view (40X).

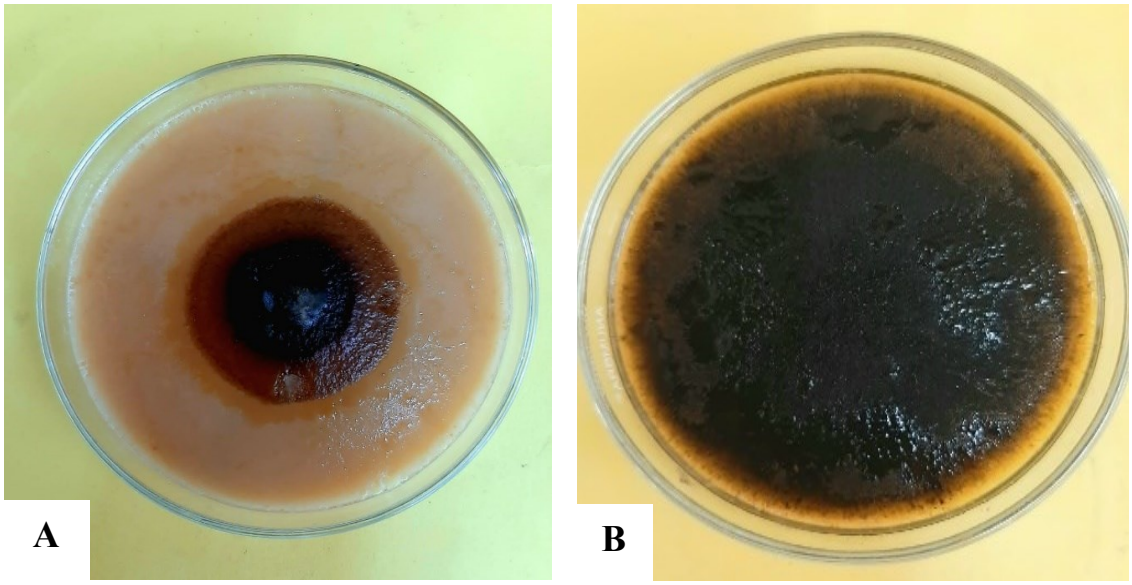


Plate 3. Pure culture of *Alternaria solani,* A. After 3 days; B. After 7 days.

4.1.3 Disease incidence and severity of Early blight

The disease incidence and severity of early blight among 19 seed potato varieties were varied significantly ($p< 0.05$) at three observed dates i.e., 45, 60 and 75 days after sowing (DAS) of potato (Table 4). At 45 DAS, the maximum incidence (23.33%) of early blight was observed in Labella variety with statistically similar to BARI Alu-79 (21.67%), Carollas (21.67%),), Aluity (20%), Asterix (20%), BARI Alu-37 (20%), Diamant (20%), Granola (20%), Innovator (20%), Prada (20%), Queen Anne (20%) and Santana (20%). The minimum incidence (10%) was observed in Sagita variety. At this DAS the disease severity was found to be maximum (12.67%) in innovator with carollas (11.33%) and Aluity (12.33%). The minimum severity (6%) was observed in Sunshine variety. However, considering both incidence and severity of early blight at 45 DAS, four seed potato varieties viz. Alkender, BARI Alu-40, Sagita and Sunshine were found to be least affected. At 60 DAS, the incidence of early blight was maximum (56.67%) in BARI Alu-79 and minimum (33.33%) was in BARI Alu-40. In case of severity, the maximum (23.67%) was observed in Granola with similar to Aluity (21%), BARI Alu-41 (22.33%), Carollas (22%), Diamant (20.67%), Innovator (22%) and Santana

(21.33%). The lowest severity (13%) was found in BARI Alu-40 with Cardinal (13.67%) and Sagita (14.67%). Considering both the incidence and severity at this DAS, the BARI Alu-40, Cardinal and Sagita showed lowest influence by early blight disease. At 75 DAS, the highest incidence (75%) was seen in BARI Alu-79, Diamant and Santana with similar to BARI Alu-37 (73.33%), Innovator (22%) and Labella (22%). The lowest incidence (55%) was in Asterix and Sunshine with similar to Sagita (56.67%), BARI Alu- 40 (58.33%) and Cardinal (60%). In case severity, it was maximum (39%) in Aluity and Prada. The lowest severity was observed in BARI Alu-40 (24%) with similar to Cardinal (25%). Considering both the incidence and severity of early blight at 75 DAS, the variety named BARI Alu-40 and Cardinal were seemed to be least affected. Overall, in three observing period, the seed potato production with these 19 varieties showed Aluity, BARI Alu-79 and Innovator was much affected to early blight of potato disease while BARI Alu-40, Cardinal and Sagita were least affected.

Table 4. Disease incidence and severity of early blight of potato at different growth stage of seed potato varieties

Varieties	45 DAS		60 DAS		75 DAS	
	DI	DS	DI	DS	DI	DS
Alkender	15±2.9c-e	7.67±0.9e-i	41.67±1.7b-d	17.67±1.5de	65±2.9c-e	30±1.2e-h
Aluity	20±2.9a-c	12.33±1.5ab	43.33±4.4bc	21±2.1a-c	63.33±1.7c-f	39±0.6a
Asterix	20±2.9a-c	8.33±0.9d-h	45±2.9b	19.67±1.2b-d	55±2.9g	31.33±0.9d-g
BARI alu-35	11.67±1.7de	8.67±0.9d-g	36.67±1.7c-e	19±0.6cd	66.67±3.3b-d	26.33±1.2ij
BARI alu-37	20±2.9a-c	7.67±0.3e-i	46.67±4.4b	20±1.5b-d	73.33±4.4ab	32±0.6c-f
BARI Alu-40	15±2.9c-e	6.33±0.9hi	33.33±1.7e	13±1.2f	58.33±1.7e-g	24±0.6j
BARI Alu-41	15±2.9c-e	9.33±0.9c-f	40±2.9b-e	22.33±1.5ab	70±2.9a-c	34.67±1.2bc
BARI Alu-79	21.67±4.4ab	10.33±0.9b-d	56.67±4.4a	20±1.2b-d	75±2.9a	32.33±0.9c-e
Cardinal	16.67±1.7b-d	6.67±0.7g-i	40±2.9b-e	13.67±0.9f	60±2.9d-g	25±2.1j
Carollas	21.67±1.7ab	11.33±0.9a-c	41.67±4.4b-d	22±1.2a-c	66.67±4.4b-d	33.67±0.7b-d
Diamant	20±2.9a-c	10.33±0.9b-d	40±2.9b-e	20.67±1.8a-d	75±2.9a	35.33±0.9b
Granola	20±2.9a-c	9.67±1.2c-e	41.67±1.7b-d	23.67±1.2a	61.67±3.3d-g	34±1.2b-d
Innovator	20±2.9a-c	12.67±0.9a	45±2.9b	22±1a-c	70±2.9a-c	33.33±1.2b-d
Labella	23.33±3.3a	7.67±0.9e-i	45±2.9b	17.67±0.7de	70±2.9a-c	28.33±0.9hi
Prada	20±2.9a-c	8±0.6e-i	40±2.9b-e	17.67±0.7de	66.67±4.4b-d	39±0.6a
Queen Anne	20±2.9a-c	9.33±0.7c-f	43.33±1.7bc	20±1b-d	56.67±3.3fg	29.33±0.7f-h
Sagita	10±2.9e	7.33±0.9f-i	40±2.9b-e	14.67±0.7ef	56.67±3.3fg	29±0.6g-i
Santana	20±2.9a-c	9±0.6d-f	43.33±4.4bc	21.33±0.9a-c	75±2.9a	33±1.2b-d
Sunshine	15±2.9c-e	6±0.6i	35±2.9de	19.33±0.7b-d	55±2.9g	31.33±0.7d-g
Significance	***	***	***	***	***	***
p value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD	5.25	2.19	7.58	3.08	8.30	2.67

4.2 Late blight disease symptoms with their causal agents

4.2.1 Symptoms

Typical late blight of potato symptoms appeared as like irregular water-soaked lesions started from border of the leaves of infected plant which rapidly turns into brown. The disease makes its appearance as small, dead, brownish to purplish black areas or lesions. These appear on the tips and margins of the leaflets, rachis, petiole, and stem. Under favorable conditions (low temperature and high humidity) the infected leaf was increased in size which involved more areas and died (Plate 4).

4.2.2 Isolation and identification of fungus (*P. infestans*)

Frugal growth was collected from disease infected leaves which observed under microscope and found that lemon shaped sporangium of *P. infestans* and thus fungus was identified (Plate 4). In pure culture the fungal colony was initially white and fluffy. The mycelium is white and fluffy; the colony is rather sluggish developing. Growth charges can vary dramatically amongst isolates, however fast-developing isolates can cowl a 9-cm plate within 10-15 days.

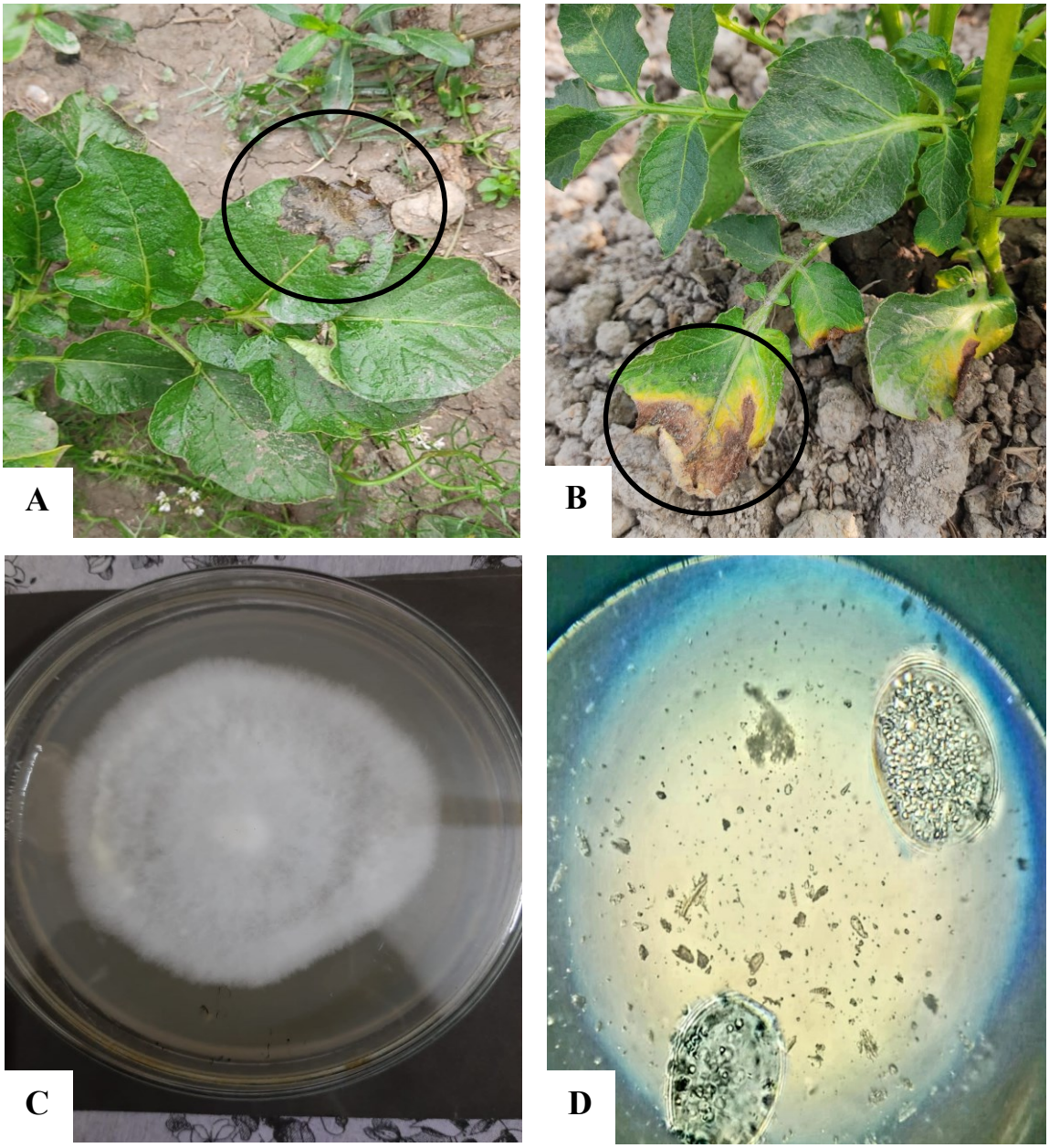


Plate 4. Late blight symptoms and identification of fungus; A. Symptom first appeared as dark brown to black in color spots; B. Dark brown prominent symptoms appeared on leaf margins; C. Pure culture of *P. infestans*; E. Compound microscopic view (40X).

4.2.3 Disease incidence and severity of Late blight

The incidence and severity of late blight disease in seed potato of 19 variety were varied significantly ($p<0.05$) among them at three observed period viz. 45 DAS, 60 DAS and 75 DAS (Table 5). At 45 DAS, the highest incidence of disease was observed in Labella (28.33%) with statistically similar to Asterix (26.67%), Carollas (26.67%), Cardinal (23.33%) and Queen Anne (23.33%). The lowest frequency of incidence (13.33%) was observed in BARI Alu-40, BARI Alu-41, and BARI Alu-79 combinedly and was statistically similar to Diamant (16.67%), Santana (16.67%) and Sunshine (18.33%). In case of severity of the disease, the highest frequency was observed in Cardinal (10%) followed by Asterix (9%). The lowest frequency of severity was in Prada (5.33%) with BARI Alu-35 (6.33%), BARI Alu-37 (6.67%), BARI Alu-40 (6%), BARI Alu-79 (6.67%), Diamant (6%), Granola (6%) and Innovator (6.67%). Asterix and Cardinal were seemed to be highly infected by late blight at 45 DAS while BARI Alu-40, BARI Alu-79 and Diamant was least. At 60 DAS, the frequency of incidence was highest (50%) in both Cardinal and Carollas that followed by Asterix (45%). However, the lowest incidence was in BARI Alu-41 (23.33%) followed by BARI Alu-79 (28.33%). The severity was also maximum in Cardinal (20%) followed by Asterix (19.33%), Labella (19.33%), BARI Alu-41 (18.67%), Carollas (18.33%), Innovator (18.33%) and Queen Anne (18.33%). The minimum frequency of severity was in Prada (11%) followed by Diamant (12.33%). Considering both the incidence and severity, Cardinal and Asterix was found to be most affected, and BARI Alu-79 was least affected. At 75 DAS, the highest disease incidence percentage was seen in cardinal (71.67%) which was statistically similar to Asterix (70%), Aluity (68.33%), Prada (68.33%), Innovator (66.67%), Labella (65%), BARI Alu-37 (65%), BARI Alu-40 (63.33%), Carollas (63.33%) and Queen Anne (63.33%). The incidence was minimum (48.33% in BARI Alu-41 and BARI Alu-79 followed by Diamant (50%) and Sunshine (55%). The frequency of severity was also maximum in Cardinal (32.67%) followed by Asterix (31.33%) and Sunshine (30.33%). The minimum severity was in BARI Alu-40 (22.33%) that was similar to BARI Alu-37 (22.67%), Diamant (23%), Prada (24%) and BARI Alu-35 (24.33%). Considering both the

disease incident and severity, Cardinal and asterix was found to be highly infected by late blight disease at 75 DAS while Diamant was least infected. The seed potato variety named BARI Alu-79 and Diamant showed better performance against late blight of potato disease while Cardinal, Asterix and Carollas were highly infected by the disease.

Table 5. Disease incidence and severity of late blight of potato at different growth stage of seed potato varieties

Varieties	45 DAS		60 DAS		75 DAS	
	DI	DS	DI	DS	DI	DS
Alkender	20±2.9cd	8.33±0.3bc	40±2.9b-d	15.33±0.3de	58.33±4.4c-e	27.33±0.7c-f
Aluity	21.67±1.7b-d	7.33±0.7c-e	43.33±3.3b	17.67±1.5bc	68.33±3.3ab	29±1.7b-e
Asterix	26.67±1.7ab	9±0.6ab	45±2.9ab	19.33±0.3ab	70±2.9ab	31.33±0.9ab
BARI alu-35	21.67±1.7b-d	6.33±0.3ef	41.67±1.7bc	14.67±0.3d-f	58.33±3.3c-e	24.33±0.7g-i
BARI alu-37	20±2.9cd	6.67±0.3d-f	35±2.9de	13.33±0.3fg	65±2.9a-c	22.67±0.7i
BARI Alu-40	13.33±1.7e	6±0.6ef	33.33±1.7ef	14±0.6e-g	63.33±1.7a-d	22.33±0.9i
BARI Alu-41	13.33±1.7e	8.33±0.3bc	23.33±1.7g	18.67±0.7ab	48.33±1.7f	27.33±0.9c-f
BARI Alu-79	13.33±1.7e	6.67±0.3d-f	28.33±1.7fg	18±0.6b	48.33±1.7f	27.67±1.5c-f
Cardinal	23.33±1.7a-c	10±0.6a	50±2.9a	20±1.2a	71.67±3.3a	32.67±1.5a
Carollas	26.67±1.7ab	7±0.6c-e	50±2.9a	18.33±0.9ab	63.33±4.4a-d	26.33±0.9f-h
Diamant	16.67±1.7de	6±0.6ef	31.67±1.7ef	12.33±1.5gh	50±2.9ef	23±0.6i
Granola	21.67±1.7b-d	6±0.6ef	35±2.9de	14.33±0.7d-f	61.67±4.4b-d	26.33±1.2f-h
Innovator	20±2.9cd	6.67±0.9d-f	43.33±1.7b	18.33±0.9ab	66.67±4.4a-c	27±1.7d-f
Labella	28.33±1.7a	8.33±0.7bc	43.33±1.7b	19.33±0.7ab	65±2.9a-c	29.67±0.9bc
Prada	20±2.9cd	5.33±0.3f	41.67±1.7bc	11±0.6h	68.33±1.7ab	24±0.6hi
Queen Anne	23.33±1.7a-c	7±0.6c-e	43.33±1.7b	18.33±0.9ab	63.33±1.7a-d	29.33±1.5b-d
Sagita	20±2.9cd	7±0.6c-e	40±2.9b-d	14.67±0.3d-f	58.33±4.4c-e	26.67±0.9e-g
Santana	16.67±1.7de	8±0.6b-d	36.67±1.7c-e	16±0.6cd	58.33±1.7c-e	25.67±1.5f-h
Sunshine	18.33±1.7c-e	7.33±0.3c-e	40±2.9b-d	15.67±0.7de	55±5d-f	30.33±0.9ab
Significance	***	***	***	***	***	***
P (>F)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD	5.42	1.43	6.00	1.99	8.53	2.34

4.3 *PLRV* disease

4.3.1 *PLRV* symptoms

The *Potato leaf roll virus* (*PLRV*) symptoms appeared as the rolling of upper leaves, which then become discolored, ranging from a lightish green to yellow color. The leaves curled up around the midrib and may assume a leathery texture. Plants usually were yellowed and stunted, and older (lower) leaves may brown and die early. Leaf rolling occurs first on upper (younger) leaves; leaves was pale green or chlorotic, with purple or reddish borders (Plate 5). Based on the characters and symptoms it was identified as *potato leaf roll virus* (*PLRV*).

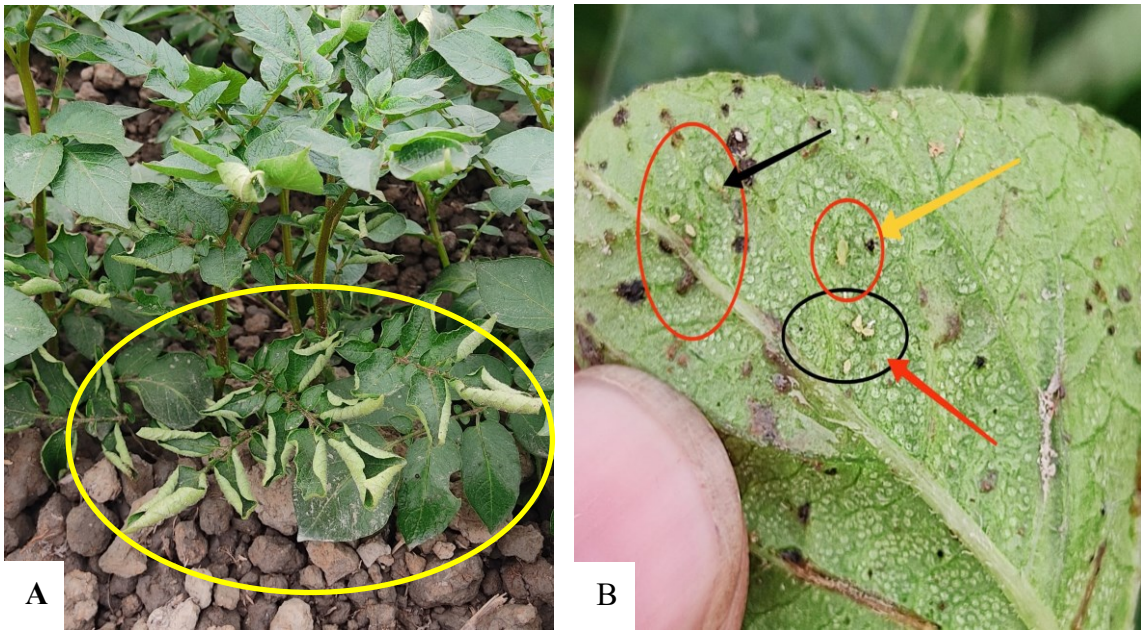


Plate 5. *PLRV* symptoms and vector, A. Symptom appeared as rolling of leaves; B. Vector of *PLRV* (Aphid).

4.3.2 Disease incidence and severity of *potato leaf roll virus* (*PLRV*)

The variety BARI Alu-40 was devoid of any infestation by *PLRV* at all three-observation period and BARI Alu-79 was free from *PLRV* at 45 DAS. Except that, the frequency of percent disease incidence and severity were varied among the seed potato varieties significantly ($p<0.05$) in all three observed period viz. at 45 DAS, 60 DAS and 75 DAS (Table 6). At 45 DAS, the highest frequency of *PLRV* incidence (18.33%) was observed in Cardinal and Sagita seed potato variety followed by BARI Alu-41 (16.67%), Labella (16.67%), Aluity (15%), Queen Anne (15%), Asterix (13.33%), BARI Alu-35 (13.33%), Diamant (13.33%) and Sunshine (13.33%). The incidence was the lowest in Innovator (4.67%) with Santana (5%), Prada (6.67%), Alkender (8.33%) and BARI Alu-37 (8.33%). The severity at 45 DAS was highest in Sagita (7.33%) with Labella (7%). However, severity of *PLRV* at 45 DAS was the lowest in innovator (1.67%) with santana (2%), BARI Alu-37 (2%), and Asterix (2.67%).

At 60 DAS, incidence of *PLRV* was maximum (43.33%) in BARI Alu-41 and Sagita with Aluity (41.67%), Labella (41.67%), Prada (41.67%), Cardinal (40%) and Carollas (40%). The lowest incidence was found in BARI Alu-79 (6.67%) and then in santana (23.33%) and in innovator (25%). The severity was maximum in BARI Alu-41 (16.33%) and then followed by Carollas (13.67%), Aluity (13.33%), Labella (13.33%) and Sagita (13.33%). The lowest percentage of severity was in BARI Alu-79 (3%) and followed BARI Alu-37 (7%), Santana (7.67%) and Innovator (9%). Considering both incident and severity, BARI Alu-41, Aluity, Carollas and Labella was highly influenced by PLR while infection in BARI Alu-79, Innovator and Santana was less.

At 75 DAS, highest incidence by *PLRV* was in Labella (85%) and then followed by BARI Alu-41 (78.33%), Sagita (78.33%), Aluity (76.67%), Queen Anne (75%), Granola (75%), Diamant (73.33%) and Prada (73.33%). The lowest incidence was at BARI Alu-79 (23.33%) and then followed by Santana (56.67%) and Innovator (66.67%). The highest severity of the disease was at Sagita (34.33%) with Labella (33.33%) and then followed by BARI Alu-41 (32.33%) and Aluity (32.33%). The lowest severity was at BARI Alu-79 (11%) and then followed by BARI Alu-37 (18.33%) and Santana (20.67%). Considering both the incidence and severity frequency, the Labella, Sagita, BARI Alu-41 and Aluity were affected most while BARI Alu-79 and Santana infected less.

Table 6. Disease incidence and severity of *PLRV* of potato at different growth stage of seed potato varieties.

Varieties	45 DAS		60 DAS		75 DAS	
	DI	DS	DI	DS	DI	DS
Alkender	8.33±1.7c-e	4.67±0.3de	33.33±1.7c	10±0.6de	70±2.9d-g	23.67±1.3d
Aluity	15±2.9ab	4.67±0.3de	41.67±1.7ab	13.33±0.9bc	76.67±1.7bc	32.33±1.5ab
Asterix	13.33±1.7a-c	2.67±0.7fg	33.33±1.7c	10.67±0.3de	75±2.9b-d	23±1.2d
BARI alu-35	13.33±1.7a-c	4.67±0.3de	33.33±1.7c	10.33±0.9de	68.33±1.7e-h	23±1.5d
BARI alu-37	8.33±1.7c-e	2±0.6g	33.33±1.7c	7±0.6g	68.33±1.7e-h	18.33±0.9e
BARI Alu-40	0±0	0±0	0±0	0±0	0±0	0±0
BARI Alu-41	16.67±1.7ab	6±0.6bc	43.33±1.7a	16.33±0.9a	78.33±1.7b	32.33±1.5ab
BARI Alu-79	0±0	0±0	6.67±1.7e	3±0.6h	23.33±1.7j	11±0.6f
Cardinal	18.33±1.7a	6±0.6bc	40±2.9ab	11.33±0.9cd	65±2.9gh	22.67±1.2d
Carollas	11.67±1.7b-d	4.67±0.3de	40±0ab	13.67±0.9b	71.67±1.7c-f	30±1.2bc
Diamant	13.33±1.7a-c	3.67±0.3ef	33.33±1.7c	11±0.6de	73.33±1.7b-e	22±1.2d
Granola	11.67±1.7b-d	5±0cd	31.67±1.7c	11±0.6de	75±2.9b-d	22.33±1.5d
Innovator	4.67±0.3e	1.67±0.3g	25±5d	9±0.6e-g	66.67±1.7f-h	22.67±1.2d
Labella	16.67±1.7ab	7±0.6ab	41.67±1.7ab	13.33±0.9bc	85±2.9a	33.33±0.9a
Prada	6.67±1.7de	4.67±0.3de	41.67±1.7ab	9.33±0.7d-f	73.33±1.7b-e	23.33±0.9d
Queen Anne	15±2.9ab	6±0.6bc	36.67±1.7bc	11±0.6de	75±2.9b-d	27.67±1.5c
Sagita	18.33±1.7a	7.33±0.7a	43.33±1.7a	13.33±0.9bc	78.33±1.7b	34.33±1.2a
Santana	5±0e	2±0g	23.33±1.7d	7.67±0.3fg	56.67±1.7i	20.67±0.7de
Sunshine	13.33±1.7a-c	4.67±0.3de	31.67±1.7c	10±0.6de	63.33±1.7h	22±1.7d
Significance	***	***	***	***	***	***
P (>F)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD	5.17	1.30	5.76	2.04	6.20	3.22

4.4 Common scab disease of potato

4.4.1 Common Scab symptoms

The symptoms of common scab visible to the naked eye on the tuber are small, usually purple, brown like swellings up to 2 mm in diameter seen most frequently at distal end of young tubers. As every lesion matures it becomes a shallow hole packed with a powdery mass of resting spores of the pathogen and is appropriately called a scab. It usually has an effect on the best outer tissues however every now and then they may penetrate greater deeply, correctly destroying a massive proportion of a tuber. The margins of mature scabs are clean in define and slightly raised with at the same time as the scab itself feels barely spongy, like cork, therefore the alternative call for the disorder corky scab. Although man or woman scabs are more or less round with a diameter of usually less than 10 mm, they regularly merge, particularly if a tuber is closely infected, resulting in large lesions with irregular outlines. The disorder can also provide upward thrust to tumors (galls, warts, and cankers) on a tuber (Plate 6). Based on the characters and symptoms it was identified as common scab of potato.

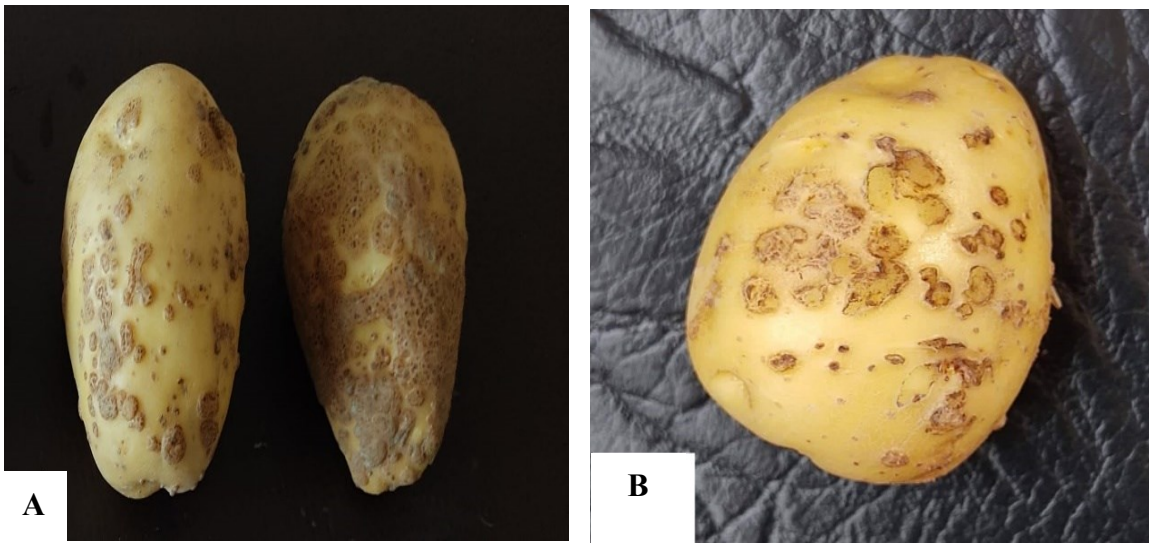


Plate 6. Common Scab symptoms, A. Symptoms of common scab of potato B. Initial affected potato tuber.

4.4.2 Disease incidence and severity of Scab in seed potato varieties

The scab in the tuber of seed potato production field was evaluated at the harvesting stage and found out of nineteen a total of thirteen varieties viz. Alkender, Aluity, BARI alu-35, BARI alu-37, BARI alu-40, BARI alu-41, BARI alu-79, Granola, Innovator, Labella, Queen Anne, Sagita and Sunshine were totally free from scab disease. The scab was found in Asterix, Cardinal, Carollas, Diamant, Prada and Santana were varied significantly ($p<0.05$) among them in terms of incidence and severity (Table 7). However, the highest incident and severity was observed in Diamant (35.48% and 17.85%) and Asterix variety (33.37% and 18.65%). The lowest incidence and severity were seen in Prada (5.52% and 1.38%) and Carollas variety (5.98% and 1.54%).

Table 7. Disease incidence and severity of scab of potato at different growth stage of seed potato varieties

Varieties	Scab in tuber at harvesting	
	DI (Mean ± SEM)	DS (Mean ± SEM)
Alkender	0±0	0±0
Aluity	0±0	0±0
Asterix	33.37±0.7a	18.65±0.4a
BARI alu-35	0±0	0±0
BARI alu-37	0±0	0±0
BARI Alu-40	0±0	0±0
BARI Alu-41	0±0	0±0
BARI Alu-79	0±0	0±0
Cardinal	28.54±0.7b	9.64±0.6b
Carollas	5.98±0.5d	1.54±0c
Diamant	35.48±1.2a	17.85±0.4a
Granola	0±0	0±0
Innovator	0±0	0±0
Labella	0±0	0±0
Prada	5.52±0d	1.38±0c
Queen Anne	0±0	0±0
Sagita	0±0	0±0
Santana	16.66±0.5c	9.33±0.2b
Sunshine	0±0	0±0
Significance	***	***
P (>F)	<0.01	<0.01
LSD	2.31	1.09

4.5 Growth of the seed potato varieties at different stage

The growth of the seed potato plant was varied significantly ($p<0.05$) among the varieties which were measured in terms of plant height, number of tillers per plant (Table 8) and number of leaves per plant (Table 9) at three growth stage viz. 45 DAS, 60 DAS and 75 DAS. At 45 DAS the plant height (cm) was maximum combinedly at BARI Alu-41 (55.46 cm), Aluity (55.15 cm) and Asterix (54.6 cm) and then followed by BARI Alu-79 (52.31 cm), BARI Alu-35 (52.38 cm) and Diamant (51.63 cm). The plant height was found to be shortest in Sunshine (25.49 cm) followed by Queen Anne (28.44 cm) and Sagita (29.75 cm). At 60 DAS the plant was found to be tallest again in BARI Alu-41 (64.65 cm) and then followed by Asterix (62.52 cm), BARI Alu-35 (62.06 cm), BARI Alu-79 (61.73 cm) and BARI Alu-40 (61.36 cm). The plant was found to be shortest in Sunshine (32.53 cm) and Queen Anne (36.97 cm). The plant height was maximum in BARI Alu-35 (103.49 cm) at 75 DAS, followed by BARI Alu-41 (87.52 cm). However, it was the lowest in Sunshine again (34.4 cm) followed by Queen Anne (38.92 cm). In general, varieties named Asterix, BARI Alu-35, BARI Alu-41, and BARI Alu-79 were seemed to be taller varieties while Queen Anne and sunshine have short stature.

In case of number of leaves plant^{-1} the variety named BARI Alu-40 (41.33), BARI Alu-41 (41.21) and BARI Alu-79 (41.45) produced maximum number of leaves at 45 DAS followed by Innovator (39.38) and BARI Alu-35 (37.9). However, the lowest number of leaves plant^{-1} was found in Queen Anne (10.3). At 60 DAS, maximum leaves were found in BARI Alu-35 (61.6) and BARI Alu-41 (62.16) combinedly that followed by BARI Alu-40 (57.27). The lowest number of leaves were observed at Queen Anne (30.51) and Labella (28.59) combinedly. At 75 DAS, the maximum number of leaves were also observed again in BARI Alu-41 (82.3) followed by BARI Alu-35 (75.14). The lowest number of leaves were in Prada (31.54) followed by Labella (33.54) and Sunshine (34.09). The varieties like BARI Alu-35, BARI Alu-40 and BARI Alu-41 were seemed to be leafy while Labella, Queen Anne and Sunshine were seemed to be less leafy (Table 9).

In case of number of tillers plants^{-1} at 45 DAS, maximum number of tillers were found in Cardinal (4.07), BARI Alu-35 (4.03), BARI Alu-41 (4.01) and BARI Alu-79 (4.01). The lowest number of tillers were in Santana (2.03) and Prada (2.07). At 60 DAS, tiller number was maximum in Cardinal again (4.3) followed by BARI Alu-41 (4.16) and BARI Alu-79 (4.16). The lowest number of tillers were again observed in Prada (2.2) and Santana (2.25).

At 75 DAS, the tiller number was maximum in Cardinal (4.34), BARI Alu-41 (4.39) and BARI Alu-35 (4.32) combinedly and followed by BARI Alu-79 (4.23). However, the lowest number of tiller (2.25) was in Prada and Santana combinedly. In general, the varieties like BARI Alu-35, BARI Alu-41, BARI Alu-79 and Cardinal were found to be more capable of producing higher number of tiller while Prada and Santana produce less. Based on the three growth related parameters the varieties like BARI Alu-35, BARI Alu-41 and BARI Alu-79 were found vigorous and Prada, Queen Anne, Santana and Sunshine were less vigor.

Table 8. Plant height and Number of tiller plant^{-1} in seed potato varieties at different growth period

Varieties	Plant height (cm)			No of tiller plant^{-1}		
	45 DAS	60 DAS	75 DAS	45 DAS	60 DAS	75 DAS
Alkender	29.52±0.7h	40.16±0.2h	47.95±1.3i	2.48±0.02j	3.05±0.04g	3.18±0.01i
Aluity	55.15±0.6a	55.53±0.6c	58.9±0.5f	2.29±0.02k	2.34±0.01i	2.65±0.06k
Asterix	54.6±0.8a	62.52±0.5b	63.78±0.8e	3.9±0.01b	4.02±0.04c	4.04±0.04c
BARI alu-35	52.38±1.2b	62.06±0.9b	103.49±1.1a	4.03±0.06a	4.17±0.01b	4.32±0.02a
BARI alu-37	31.58±0.4g	52.74±1.4e	72.69±0.8c	3.09±0.01ef	3.21±0.02f	3.33±0.02h
BARI Alu-40	50.52±0.9c	61.36±0.7b	66.9±0.9d	3.15±0.03de	3.21±0.01f	3.6±0.04f
BARI Alu-41	55.46±0.7a	64.65±0.9a	87.52±0.9b	4.01±0.08a	4.16±0.04b	4.39±0.03a
BARI Alu-79	52.31±0.6b	61.73±0.5b	65.34±0.7de	4.01±0.05a	4.16±0.03b	4.23±0.02b
Cardinal	40.49±1.1ef	43.24±0.6fg	48.24±1i	4.07±0.02a	4.3±0.02a	4.34±0.01a
Carollas	39.18±0.4f	53.05±1de	55.55±0.7g	3.2±0.03d	3.39±0.02e	3.7±0.06e
Diamant	51.63±0.4bc	54.55±0.6c-e	63.57±0.4e	2.3±0.03k	3.01±0.1gh	3.45±0.03g
Granola	32.7±0.5g	42.5±0.4fg	43.32±0.4j	2.9±0.02h	2.93±0.01h	3.05±0.03j
Innovator	41.53±0.4ef	44.07±0.8fg	46.73±0.5i	3.19±0.02d	3.27±0.06f	3.82±0.08d
Labella	32.47±0.6g	39.32±0.6h	43.39±0.7j	3±0.03g	3.11±0.01g	3.31±0.01h
Prada	40.08±0.7ef	42.28±0.5g	54.12±0.8g	2.07±0.04l	2.2±0.03j	2.35±0.01l
Queen Anne	28.44±0.7h	36.97±1.3i	38.92±0.2k	3.5±0.01c	3.6±0.01d	4.33±0.02a
Sagita	29.75±0.6h	44.28±0.9f	50.71±0.7h	2.77±0.01i	3.08±0.05g	3.3±0.02h
Santana	45.03±0.5d	54.96±1.2cd	66.34±1.2d	2.03±0.04l	2.25±0.03ij	2.35±0.01l
Sunshine	25.49±0.7i	32.53±0.7j	34.4±1.2l	3.02±0.02fg	3.09±0.02g	3.3±0.01h
Significance	***	***	***	***	***	***
P (>F)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
LSD	1.78	1.93	2.27	0.09	0.10	0.08

Table 9. Number of leaves plant^{-1} in seed potato varieties at different growth period

Varieties	No of leaves plant^{-1}		
	45 DAS	60 DAS	75 DAS
Alkender	28.28±1e	39.89±1g	45.91±1.2i
Aluity	34.57±0.7c	40.01±0.4g	42.82±0.4j
Asterix	32.08±0.9d	55.2±0.5c	56.63±0.4f
BARI alu-35	37.9±0.8b	61.6±0.8a	75.14±1.1b
BARI alu-37	21.18±0.9h	39.78±0.7g	58.61±0.6e
BARI Alu-40	41.33±1.2a	57.27±0.7b	64.43±0.6c
BARI Alu-41	41.21±1a	62.16±1.2a	82.3±0.9a
BARI Alu-79	41.45±0.6a	49.53±0.6e	52.3±0.5g
Cardinal	34.09±0.9c	51.69±0.9d	61.92±0.7d
Carollas	30.41±0.7d	44.92±0.8f	49.02±0.7h
Diamant	35.37±0.7c	43.11±0.6f	59.1±0.5e
Granola	23.55±1fg	38.38±0.7g	43.2±0.6j
Innovator	39.38±0.9b	47.69±0.5e	56.93±0.6f
Labella	25.22±0.7f	28.59±0.8k	33.54±0.8k
Prada	21.17±0.5h	30.83±0.3ij	31.54±0.5l
Queen Anne	10.3±0.5j	30.51±0.9jk	45.4±0.5i
Sagita	22.51±0.7gh	34.86±0.7h	43.42±0.4j
Santana	27.08±0.9e	47.57±0.6e	52.31±0.9g
Sunshine	13.23±0.8i	32.68±0.5i	34.09±0.6k
Significance	***	***	***
P (>F)	<0.01	<0.01	<0.01
LSD	1.69	2.03	1.67

4.6 Yield contributing character of seed potato varieties

4.6.1 The grade of tuber by diameter

The yield contributing parameters like grade of the tubers were significantly ($p<0.05$) differs among the nineteen varieties (Table 10). The tuber produced by the varieties were categorized into 4 groups based on the diameter (mm) of the tuber and found that Cardinal, Carollas, Diamant, Granola, Innovator and Prada does not produce tuber having diameter more than 55 mm. Cardinal produces maximum percentage (53.79%) of grade C (<28mm) types of tubers followed by Diamant (51.18%). The lowest percentage of grade C tuber were produced in Innovator (9.5%) followed by Santana (20.04%). The maximum percentage of grade B2 (28-44 mm) types of tubers were produced by BARI Alu-79 (57.78%), Prada (51.95%) and BARI Alu-40 (51.78%) jointly that followed by Granola (47.42%) and BARI Alu-35 (46.75%). The lowest frequency was seen in BARI Alu-41 (21.94%), cardinal (27.73%) and Sunshine (26.53%). The maximum percentage of tuber in grade B1 (45-55mm) were seen in Innovator (60.17%) followed by Sunshine (38.36%). The least was produced by BARI Alu-35 (3.35%) and Granola (4.41%). The frequency of producing grade A (>55mm) size tuber was comparatively low but maximum percentage was observed in Aluity (5.81%) and BARI Alu-79 (5.27%) and then followed by BARI Alu-40 (4.6%) and Labella (4.63%). The seldom was found in Alkender (1.33%) and Sagita (1.95%).

Table 10. Grade of tuber by diameter of seed potato varieties

Varieties	Grade of tuber by diameter (%)			
	<28 mm (C)	28-44 mm (B2)	45-55 mm (B1)	>55mm(A)
Alkender	43.09±2.2ef	38.75±0.9ef	16.83±2.1f	1.33±0.03h
Aluity	29.13±0.2ij	35.43±1.2f-h	29.63±1.1d	5.81±0.1a
Asterix	44.92±0.8de	31.12±0.2g-i	21.37±0.7e	2.59±0.03fg
BARI alu-35	46.52±0.6cd	46.76±0.6b-d	3.35±0.03j	3.37±0.04d-f
BARI alu-37	32.95±0.9gh	40.21±1.1d-f	23.52±0.3e	3.32±0.02d-f
BARI Alu-40	29.75±0.4ij	51.78±0.3ab	13.86±0.2g	4.6±0.03bc
BARI Alu-41	41.62±0.9f	21.94±9.2j	23.59±0.6e	3.85±0.03cd
BARI Alu-79	26.37±0.4kl	57.36±1a	11±0.6h	5.27±0.02ab
Cardinal	53.79±0.6a	27.73±1.2ij	18.47±0.6f	0±0
Carollas	24.27±0.6l	41.14±0.3c-f	34.59±0.4c	0±0
Diamant	51.18±1b	41.97±0.9c-f	6.72±0.2i	0±0
Granola	48.17±0.7c	47.42±0.8bc	4.41±0.1ij	0±0
Innovator	9.5±0.3n	30.33±1.1hi	60.17±0.9a	0±0
Labella	41.9±0.8f	35.98±0.3f-h	17.68±1.6f	4.63±1bc
Prada	26.78±1.4jk	51.95±1.2ab	21.27±0.8e	0±0
Queen Anne	42.82±0.8ef	37.37±0.8fg	17.02±0.4f	2.78±0.01ef
Sagita	35.14±0.6g	44.84±1.2c-e	18.07±0.7f	1.95±0.03gh
Santana	20.04±0.7m	40.66±0.7d-f	35.77±0.4c	3.54±0.02de
Sunshine	30.74±0.3hi	26.53±0.5ij	38.36±0.6b	4.37±0.02c
Significance	***	***	***	***
P (>F)	<0.01	<0.01	<0.01	<0.01
LSD	2.50	6.68	2.40	0.82

4.6.2 Number of tubers hill^{-1} and weight of tubers hill^{-1}, seed potato tuber and non-seed potato tuber of seed potato varieties

The counted number of tubers per hill were maximum in Cardinal (18.17) followed by Granola (15.96) and BARI Alu-40 (14.51). It was jointly lowest in Carollas (5.63), Aluity (5.74), Prada (6.11), BARI Alu-79 (6.63) and Innovator (6.77). The maximum weight of tubers per hill was found to be in BARI Alu-40 (785.6 g) followed by Sunshine (759.87 g) and Cardinal (751.82 g). The lowest weight of tubers hill^{-1} was observed in BARI Alu-79 (287.05 g) followed by Diamant (348.14 g). (Table 11)

The tuber separated based on their size and disease results in that Innovator (70.62%), Aluity (70.61%) and BARI Alu-79 (69.35%) has maximum percentage of seed potato tubers. In contrast, the varieties like Santana (78.45%) and Labella (77.71%) were found to have highest amount of non-seed potato tubers followed by Asterix (71.48%) and Cardinal (71.66%). (Table 12)

Table 11. Number of tubers hill^{-1} and Weight of tubers hill^{-1} (g) of seed potato varieties

Varieties	No of tubers hill^{-1}	Weight of tubers hil^{-1} (g)
Alkender	8.51±0.2i	428.88±4.3j
Aluity	5.74±0.3j	435.05±3.9ij
Asterix	13.13±0.4de	607.88±1.7e
BARI alu-35	10.78±0.5fg	371.23±3.8kl
BARI alu-37	10.47±0.3gh	628.7±0.7d
BARI Alu-40	14.51±0.3c	785.6±9.4a
BARI Alu-41	8.66±0.3i	444.59±3.7i
BARI Alu-79	6.63±0.2j	287.05±4.7n
Cardinal	18.17±0.4a	751.82±0.8b
Carollas	5.63±0.2j	383.42±4.3k
Diamant	11.2±0.5fg	348.14±12.1m
Granola	15.96±0.4b	461.59±2.4h
Innovator	6.77±0.2j	566.4±4.2f
Labella	12.02±0.4ef	660.69±1.6c
Prada	6.11±0.1j	377.67±8.9kl
Queen Anne	13.39±1.7cd	534.91±0.9g
Sagita	8.45±0.1i	365.22±0.9l
Santana	9.29±0.2hi	663.4±7.3c
Sunshine	9.51±0.1hi	759.87±1.3b
Significance	***	***
P (>F)	<0.01	<0.01
LSD	1.24	14.96

Table 12. Seed potato tuber and non-seed potato tuber of seed potato varieties

Varieties	Seed potato tuber (%)	Non-seed potato tuber (%)
Alkender	43.41±0.8g	56.61±0.8g
Aluity	70.61±0.7a	29.39±0.7m
Asterix	28.52±0.5l	71.48±0.5b
BARI alu-35	53.5±0.7d	47.32±0.4j
BARI alu-37	40.56±0.5hi	59.44±0.5ef
BARI Alu-40	39.54±0.4ij	60.46±0.4de
BARI Alu-41	42.56±0.5g	57.44±0.5g
BARI Alu-79	69.35±0.5a	30.65±0.5m
Cardinal	28.34±0.5l	71.66±0.5b
Carollas	47.3±0.7e	52.7±0.7i
Diamant	36.06±0.7k	63.98±0.7c
Granola	45.57±0.6f	54.43±0.6h
Innovator	70.62±0.4a	29.38±0.4m
Labella	22.29±0.5m	77.71±0.5a
Prada	55.69±0.6c	44.31±0.6k
Queen Anne	41.96±0.2gh	57.95±0.3fg
Sagita	38.53±0.6j	61.46±0.6d
Santana	21.55±0.9m	78.45±0.9a
Sunshine	57.59±0.7b	42.41±0.7l
Significance	***	***
P (>F)	<0.01	<0.01
LSD	1.68	1.68

CHAPTER V

DISCUSSION

Altogether nineteen varieties of seed potato were evaluated in natural field condition to assess disease prevalence and agronomic performance. Four most important diseases of potato viz. early blight, late blight, *PLRV* and scab were identified and their incidence and severity at three growth periods were studied. Typical early blight symptoms were observed and the pathogen isolated were identified as *Alternaria solani*. Characteristic symptoms were dark brown or black lesions with concentric rings on leaves, which produced a 'target spot' effect which resembles the description of Rands (1917a). Lesions enlarged, coalesced and eventually death of the leaf. Similar symptoms of early blight were reported by Shuman (1995). According to Shuman (1995) the first to describe the symptoms on dying potato leaves. Symptoms are initially observed on older, senescing leaves (Shuman 1995). The isolated causal organism was *Alternaria solani*. It was isolated using potato dextrose agar (PDA) media as described by Schultz and French, 2009; Agrios *et al.*, 2005. The color of colony of the *A. solani* were varied from grayish to black in color having dark mycelium mostly. The conidia were found to be on branched chain possesses large, dark and pear shape cells. Agrios *et al.* (2005) reported dark-colored mycelium, and single or branched chains of conidia in older diseased tissue of which conidia are large, and pear shaped with both transverse and longitudinal structure. All of nineteen varieties studied were found to be infected by early blight and both the disease incidence and severity were increased with time. Mehboob *et al.* (2013) observed that the disease increased in suitable temperature and moisture conditions. It was observed that three varieties such as BARI Alu-40, Cardinal and Sagita showed some less infection by the early blight while varieties like Aluity, BARI Alu-79 and Innovator were more affected to early blight. (Qazi *et al.,* 2013).

The symptoms of late blight were like irregular water-soaked lesions which rapidly turns into brown. These typical symptoms similar to studied by Arora *et al*., (2014). Isolation of the pathogen was done, and which observed under microscope and

found that lemon shaped sporangium of *P. infestans* which was similar description by Agrios *et al.* (2005); Arora *et al*. (2014). Late blight also found as devastating that it infected all the nineteen seed potato varieties in all three-study period. It was observed in the entire growth period, the varieties like BARI Alu-79 and Diamant showed better performance against late blight of potato disease while Cardinal, Asterix and Carollas were highly infected by the disease. Talukder *et al.* (2021) was observed that in disease infection among the varieties BARI Alu-41 perform better compared to BARI Alu-35, BARI Alu-36, BARI Alu-37 and BARI Alu-40.

Characteristics symptoms caused by *PLRV* include rolling, and leathering of leaves were seen in potato field which was also stated by Alani *et al.* 2002. The primary symptoms include pallor or reddening of leaf tips of upper or young leaves, afterward these young leaves become roll and erect. Secondary symptoms appear on the potato crops. These symptoms consist of stunting of shoots and rolling of oldest or lower leaves upward. Secondary symptoms turned out to be more severe as compared to primary symptoms with leathery texture and overall roll of leaves (Abbas *et al*., 2016). The evaluation of *PLRV* in these nineteen seed potato varieties revealed that BARI Alu-40 was free from *PLRV* at early period but got infected later. The incidence and severity of *PLRV* was much lower than early or late blight at early stage of plant growth period but increased incidence with time hit more at late growth period exceeding others. In total considering the entire growth period the BARI Alu-40 was found to be best against *PLRV* and varieties like BARI Alu-79, BARI Alu-37, Innovator and Santana performed considerably better than that of Aluity, BARI Alu-41 and Labella. Talukder *et al.* (2021) also observed that *PLRV* infected was found in BARI Alu-40 where the lowest infection was observed in BARI Alu-41.

The symptoms of common scab visible to the naked eye are small, usually purple, brown like swellings up to 2mm in diameter seen most frequently at the end of young tubers (Osborn, 1911; Lawrence and McKenzie, 1981). As each lesion matures it becomes a shallow hollow filled with a powdery mass of resting spores of the pathogen and is appropriately known as a scab (Butler and Jones, 1949;

Whitehead *et al.*, 1953; Sprau, 1953). Scabs normally affect only the outer tissues but occasionally they may penetrate more deeply, effectively destroying a large proportion of a tuber (Whitehead *et al.*, 1953). The disease can also give rise to tumors (galls, warts, and cankers) on a tuber (Horne, 1911b; Morse, 1914; Hims and Preece,1975). The scab in the tuber of seed potato production field was evaluated at the harvesting and found out of nineteen a total of thirteen varieties. The variety Prada and Carollas was found to have low infection by scab disease while most frequency was in Cardinal, Diamant and Asterix varieties. The scab was found to be not as devastating as other diseases and there are considerable number of varieties available those can totally resist the disease during seed potato production. The highest common scab infection was observed in BARI Alu-35 where the lowest in BARI Alu-41 reported by Talukder *et al.* (2021). It was also observed that highest scab incidence was observed in Cardinal and Diamant was medium susceptible potato variety in common scab disease. (Naher *et al.,* 2013).

The growth of the seed potato plant was assessed based on the measurement of plant height, number of tillers per plant and number of leaves per plant at three growth stage. Based on the plant height (cm) it was appeared that varieties like Queen Anne, Sunshine, Granola, and Labella was short statured while BARI Alu-35, BARI Alu-41, BARI Alu-37, Asterix, BARI Alu-79, and Diamant are long statured. The tallest plant was observed in BARI Allu-41 variety. Statistically it was similar with BARI Alu-78, BARI Alu-40 and BARI Alu-36 and BARI Alu- 79 and the shortest was BARI Alu-81 and BARI Alu- 37. (Mashfiqur *et al.,* 2021; Mallick *et al.,* 2021)

The varieties like BARI Alu-35, BARI Alu-40 and BARI Alu-41 were seemed to be leafy while Labella, Queen Anne and Sunshine were seemed to be less leafy. The number of leaves increases at lower than these rate from early to late growth stage in early blight affected varieties (e.g., Aluity, Innovator and BARI Alu-79) and from mid to late growth stage in case of late blight infected varieties (Cardinal, Carollas and Asterix). The rate of leaves number increment in *PLRV* infected was not limited rather increased by double-fold if not infected by other diseases. In case

of scab disease infection, the leaf production was almost similar to normal. The maximum number of leaves was observed in Cardinal variety (Alam *et al.,* 2003)

The number of tiller plant^{-1} was also almost two-fold higher in long statured varieties than short statured varieties at all three stages. The rate of increment of tillers plant^{-1} from early stage to late stage was seemed to be harmonious in all varieties including both long and short statured despite of different kind of disease infection at different levels of severity. The disease incidence might have not influenced much the tiller production capabilities of plants (Islam *et al.,* 2019). The evaluation of yield contributing characters revealed that number of tubers per hill was an important factor influencing grade of the tuber according to size. The varieties those produces larger number of tubers per hill resulted in production of higher percentage of small size (<28mm) tubers that leads to production of high percentage of non-marketable seed tubers. But when a variety produces large number of tubers hill^{-1} then the weight of tubers per hill was higher. (Mashfiqur *et al.,* 2021; Islam *et al.,* 2019)

The varieties infected most by early blight diseases like BARI Alu-79 and Innovator produces lower number of tubers per hill that leads to larger size tuber production with higher percentage of seed tuber (marketable). BARI Alu-40 and Cardinal were infected least by early blight and depict a opposite scenario providing maximum weight of tubers per hill but most of which were non-seed tuber(non-marketable). The scenario in late blight was more damaging. Though Cardinal was better against early blight attack, it was severely infected by late blight that provides a good weight of tubers per hill but most of which were non-seed tuber. Late blight was severe in Carollas and Asterix that resulted in lower number of tubers per hill and lower percentage of seed tuber (marketable). BARI Alu-79 and Diamant was good against late blight, but BARI Alu-79 were already damaged by early blight while Diamant was subject to Scab disease with Asterix. The number of tubers hill^{-1} in Diamant was not low but produces large percentage of small size tuber resulting in higher percentage of non-seed tuber. A good number of potato varieties were found to have resistant to scab. *PLRV* was severe in Aluity, BARI Alu-42, Labella and

Sagita that leads to yield reduction in these varieties. Labella provides a good yield but most of which was non-seed tuber. (Mashfiqur *et al.,* 2021; Islam *et al.,* 2019)

However, BARI Alu-40 was found to be less affected by early blight and late blight while totally free from *PLRV* and scab. In this variety the number of tuber hill^{-1} was higher with high percentage of medium size tuber leading to maximum yield with satisfactory percentage of seed tubers.

CHAPTER VI

SUMMARY AND CONCLUSION

Potato, belongs to the family Solanaceae, is an important tuber crop grown all over the world. It is the staple food in developed countries and accounts for 37% of the total potato production in the world. Bangladesh is the 7th producer of potato in the world. Though the demand of potato is increasing day by day, it's production in terms of area and yield is not satisfactory due to different diseases of potato. Seed potato is very important for successful potato production this valuable agricultural input is vulnerable to attack by various diseases in Bangladesh. The present study was conducted to investigate prevalence of diseases in 19 seed potato varieties as well as their performance in farmer's field. The experiment was carried out in a potato cultivation land in Gowalkhali village at Sirajdikhan upzilla in Munshiganj district and the detection of pathogen was performed in Disease Diagnostic Laboratory of the Department of Plant Pathology in Sher-e-Bangla Agricultural University, Dhaka. The field experiment was laid out in randomized complete block design (RCBD) with three replications and the nineteen varieties are considered as treatments. The seed tuber of selected varieties was collected from cold storage of Bangladesh Agricultural Development Corporation (BADC), Munshiganj and the varieties were Prada, BARI Alu-40, Santana, BARI Alu-79, Innovator, Aluity, Diamant, Carollas, BARI Alu-41, BARI alu-35, BARI alu-37, Queen Anne, Granola, Asterix, Labella, Sunshine, Cardinal, Sagita, and Alkender. Symptoms were studied by visual observation. Typical symptoms were observed in experimental field. Four noted diseases viz. Early bilight of potato, Late blight, *PLRV* and common scab were identified and their causal agent viz. *Alternaria solani***,** *Phytophthora Infestanc* were isolated. In early blight which was dark brown or black lesions with concentric rings on leaves. Later these lesions were turned into dark brown or black lesions with concentric rings on leaves. Lesions were usually oval in form. For late blight of potato, typical symptoms appeared as like irregular water-soaked lesions started from border of the leaves of infected plant which rapidly turns into brown. Also, Potato leaf roll virus (*PLRV*) symptoms appeared as the rolling of upper leaves, which then

become discolored, ranging from a lightish green to yellow color. And symptoms of common scab were visible to the naked eye on the tuber are small, usually purple, brown like swellings up to 2mm in diameter seen most frequently at distal end of young tubers. The causal organism was isolated from infected potatoes collected from experimental site following tissue culture method. Early blight of potato caused by *Alternaria solani* and conidia were observed long beaked, dark colored, borne singly, both longitudinal and transverse septa in mature conidia. Late blight of potato caused by *Phytophthora Infestanc and* found that lemon shaped sporangium of *P. infestans.*

The disease severity and incidence of early blight, late blight, *PLRV* and common scab among 19 seed potato varieties were observed at different growth stage. In early blight, the highest incidence was seen in BARI Alu-79, Diamant and Santana and lowest disease incidence was recorded in Asterix and Sunshine. Maximum severity was observed in Aluity and Prada while the lowest severity was observed in BARI Alu-40. Result showed BARI Alu-40 and Cardinal were least affected by the recorded four diseases whereas Diamant and BARI Alu-79 were mostly affected. In late blight, the highest disease incidence was seen in cardinal, which was statistically like Asterix, and incidence was minimum in BARI Alu-41 and BARI Alu-79. For severity, it was maximum in Cardinal and minimum in BARI Alu-40. Cardinal and Asterix was found to be highly infected by late blight while Diamant were found to be least infected considering both incidence and severity. In *PLRV*, the highest disease incidence was in Labella and lowest in BARI Alu-79. For severity, the disease was highest at Sagita with Labella and lowest in BARI Alu-79. Varieties while BARI Alu-79 showed some resistant the varieties like Labella, Aluity, BARI Alu-41, and Sagita were highly infected by *PLRV*. It was evident except some varieties the *PLRV* disease also can be as devastating as blight in case of seed potato varieties. In common scab, the highest incident and severity was observed in Diamant and Asterix variety. The lowest incidence and severity were seen in Prada and Carollas variety. The variety Prada and Carollas was found to have low infection by scab disease while most frequency was in Cardinal, Diamant and Asterix varieties. The scab was found to be not as

devastating as other diseases and there are considerable number of varieties available those can totally resist the disease during seed potato production. The varieties like BARI Alu-35, and BARI Alu-41 seemed to be leafy while Prada, Labella and Sunshine seemed to be less leafy. At the long-statured plant, the number of leaves per plant was higher than the short-statured plant. The number of tillers was maximum (4.34) in Cardinal followed by BARI Alu-41 (4.39) and BARI Alu-35 (4.32) and the lowest number of tiller (2.25) was in Prada and Santana. The highest frequency of grade C (<28mm) tuber were produced by Cardinal (53.79%), B2 (28-44mm) tuber (51.78%) by BARI Alu-79 following Prada (51.95%) and BARI Alu-40 (51.78%), B1 (45-55mm) tuber (60.17%) by Innovator and A (>55mm) tuber (5.81%) by Aluity following BARI Alu-79 (5.27%). However, lowest frequency of grade C tuber (9.5%) was observed in Innovator, B2 tuber (21.94%) in BARI Alu-41 following cardinal (27.73%) and Sunshine (26.53%), B1 tuber (3.35%) in BARI Alu-35 following Granola (4.41%) and A tuber in Alkender (1.33%) and Sagita (1.95%). The counted number of tubers $hill^{-1}$(18.17%) were maximum in Cardinal and lowest (5.63%) in Carollas following Aluity (5.74%), Prada (6.11%), BARI Alu-79 (6.63%) and Innovator (6.77%). The maximum weight of tubers per hill (785.6 g) was found to be in BARI Alu-40 followed by Sunshine (759.87 g) and Cardinal (751.82 g). The lowest weight of tubers $hill^{-1}$ was observed (287.05 g) in BARI Alu-79 followed by Diamant (348.14 g).

Most significantly, BARI Alu-40 was found completely free of *PLRV* and scab while being less susceptible to early blight and late blight. This variety had greater tuber $hill^{-1}$ count, high proportion of medium-sized tubers, produced maximum yield and better percentage of marketable seed tubers.

CHAPTER VII

REFERENCES

Abbas, A., Arif, M., and Ali, M. (2016). Ismail, S., Jiang, B., Nasimi, Z., Inam-ul-Haq, M., Yamamoto, N., Danso Ofori, A., ... and Zheng, A. (2020). Investigation of Streptomyces scabies causing potato scab by various detection techniques, its pathogenicity and determination of host-disease resistance in potato germplasm. *Pathogens*, *9*(9), 760.*Asian J Agric Biol*, *4*(3), 77-86.

Abou-Hussein SD, El-Oksh I, El-Shorbagy T, El-Bahiry. A. (2002). Effect of chicken manure, compost and biofertilizers on vegetative growth, tuber characteristics and yield of potato crop. Egypt *Journal of Horticulture* 29(1):135–149.

Adams, M. J. (1975). Potato tuber lenticels: development and structure. *Annals of Applied Biology*, *79*(3), 265-273.

Adl, S. M., Simpson, A. G., Farmer, M. A., Andersen, R. A., Anderson, O. R., Barta, J. R., ... and Taylor, M. F. (2005). The new higher-level classification of eukaryotes with emphasis on the taxonomy of protists. *Journal of Eukaryotic Microbiology*, *52*(5), 399-451.

Afrin, N., Habiba, U., Das, R. R., Auyon, S. T., and Islam, M. A. (2018). Impact and vulnerability assessment on climate change of Jessore and Mymensingh districts in Bangladesh. *Progressive Agriculture*, *29*(4), 320-335.

Agrios, G. N. (2005). *Plant pathology*. Elsevier pp.106-107/ p.106.

Ahmad, K. U. (1974). Status of Potato Research in Bangladesh. *Horticultural Research Notes*, (15).

Alam, M. K., Zaman, M. M., Nazrul, M. I., Alam, M. S., and Hossain, M. M. (2003). Performance of some exotic potato varieties under Bangladesh conditions. *Asian J. Plant Sci*, *2*(1), 108-112.

Alani, R. A., Alessawi, U. N., and Almashaikhy, S. A. (2002). Isolation of proteins from Datura stramonium has ability to inhibition the multiplication of potato virus Y (PVYn). *Jerash J. Res. Studies*, *7*, 9-21.

Ali, M. S., & Dey, T. K. (1994, October). Pathological research on tuber crops in Bangladesh. In *Proc. of Workshop on Transf. of CDP crops under Res. Extn. Linkage Progm., held on Oct* (pp. 22-27).

Arora, R. K., Sharma, S., and Singh, B. P. (2014). Late blight disease of potato and its management. *Potato J*, *41*(1), 16-40.

Azad, A. K., Uddin, M., Ohab, M. A., Sheikh, M. H. R., Nag, B. L., & Rahman, M. H. H. (2020). Edited. *Krishi Projukti Hatboi (Handbook on Agro-Technology), 9th edition, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh*.

Azimuddin, M. D., Alam, Q. M., and Baset, M. A. (2009). Potato for food security in Bangladesh. *International Journal of Sustainable Crop Production*, *4*(1), 94-99.

Bahner, I., Lamb, J., Mayo, M. A., and Hay, R. T. (1990). Expression of the genome of potato leafroll virus: readthrough of the coat protein termination codon in vivo. *Journal of General Virology*, *71*(10), 2251-2256.

Baldauf, S. L., Roger, A. J., Wenk-Siefert, I., and Doolittle, W. F. (2000). A kingdom-level phylogeny of eukaryotes based on combined protein data. *Science*, *290*(5493), 972-977.

Bansode, G. M., More, S. A., Deshmukh, M. R., and Supe, V. S. (2018). Efficacy of sequential sprays of different fungicides against early blight Alternaria solani (Ellis and Martin) in potato Solanum tubrosum L. *International Journal of Pharmacy and Biological Sciences*, *8*(1), 11-15.

BBS. (2015). Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics Division, Ministry of Planning. Government of the Peoples Republic of Bangladesh, Dhaka.

BBS. (2021). Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics Division, Ministry of Planning. Government of the Peoples Republic of Bangladesh, Dhaka.

Beukema, H. P., and van der Zaag, D. E. (1990). *Introduction to potato production* (No. 633.491 B4). Wageningen: Pudoc.

Black, L. M. (1959). Biological cycles of plant viruses in insect vectors. In *The viruses* (pp. 157-185). Academic Press.

Bonde, M. R., and McIntyre, G. A. (1968). Isolation and biology of aStreptomyces sp. causing potato scab in soils below pH 5.0. *American Potato Journal*, *45*(8), 273-278.

Bouchek-Mechiche, K., Pasco, C., Andrivon, D., and Jouan, B. (2000). Differences in host range, pathogenicity to potato cultivars and response to soil temperature among Streptomyces species causing common and netted scab in France. *Plant pathology*, *49*(1), 3-10.

Butler, E. J., and Jones, S. G. (1949). Powdery scab of potato, Spongospora subterranea (Wallr.) Lagerh. *Plant Pathology*, 493-8.

Campbell, C. L., and Neher, D. A. (1994). Estimating disease severity and incidence. In *Epidemiology and management of root diseases* (pp. 117-147). Springer, Berlin, Heidelberg.

Chaudhary, A. K., Yadavb, J., Guptac, A. K., and Guptad, K. (2021). Integrated Disease Management of Early Blight (Alternaria Solani) Of Potato. *Tropical Agrobiodiversity (TRAB)*, *2*(2), 77-81.

Cooke LR, Schepers HTAM, Hermansen A, Bain RA, Bradshaw NJ, Ritchie F, Shaw DS, Evenhuis A, Kessel GJT, Wander JGN, Andersson B, Hansen JG, Hannukkala A,

Naerstad R, Nielsen BJ (2011). Epidemiology and integrated control of potato late blight in Europe. Potato Research. 54: 183-22

Day, M. F. (1955). The mechanism of the transmission of Potato leaf roll virus by aphids. *Australian Journal of Biological Sciences*, *8*(4), 498-513.

Driscoll, J. E. (2007). *In-Vitro Screening Protocol for Resistance to Common Potato Scab*. Michigan State University. Department of Crop and Soil Sciences.

Driscoll, J. E. (2007). *In-Vitro Screening Protocol for Resistance to Common Potato Scab*. Michigan State University. Department of Crop and Soil Sciences.

Ellis, M. B., and Gibson, I. A. S. (1975). Alternaria solani. [Descriptions of Fungi and Bacteria]. *CMI Descriptions of Pathogenic Fungi and Bacteria*, (48).

Elze, D. L. (1931). *The relation between insect and virus as shown in potato leaf roll and a classification of viroses based on this relation*.

Frey, W., Goodwin, S., Dyer, A., Matuszak, J., Drenth, A., Tooley, P., ... and Sandlan, K. (1993). Historical and recent migrations of P. infestans: chronology and implications. *Plant Disease*, *77*, 653-661.

Fry, W. (2008). Phytophthora infestans: the plant (and R gene) destroyer. *Molecular plant pathology*, *9*(3), 385-402.

Gado, E. A. M. (2013). Induction of resistance in potato plants against bacterial wilt disease under Egyptian condition. *Journal of Applied Sciences Research*, *9*(1), 170-177.

Garret, A., Kerlan, C., and Thomas, D. (1993). The intestine is a site of passage for potato leafroll virus from the gut lumen into the haemocoel in the aphid vector, Myzus persicae Sulz. *Archives of virology*, *131*(3), 377-392.

Gildow, F. E. (1985). Transcellular transport of barley yellow dwarf virus into the hemocoel of the aphid vector, Rhopalosiphum padi. *Phytopathology*, *75*(3), 292-297.

Gildow, F. E. (1987). Virus—membrane interactions involved in circulative transmission of luteoviruses by aphids. In *Current topics in vector research* (pp. 93-120). Springer, New York, NY.

Gildow, F. E. (1993). Evidence for receptor-mediated endocytosis regulating luteovirus acquisition by aphids. *PHYTOPATHOLOGY-NEW YORK AND BALTIMORE THEN ST PAUL-*, *83*, 270-270.

Gildow, F. E., and Rochow, W. F. (1980). Role of accessory salivary glands in aphid transmission of barley yellow dwarf virus. *Virology*, *104*(1), 97-108.

Gomez, K. A., and Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley and sons.

Goth, R. W., Haynes, K. G., Young, R. J., Wilson, D. R., and Lauer, F. I. (1995). Relative resistance of the potato cultivar Krantz to common scab caused byStreptomyces scabies as determined by cluster analysis. *American potato journal*, *72*(9), 505-511.

Goyer, C., and Beaulieu, C. (1997). Host range of streptomycete strains causing common scab. *Plant Disease*, *81*(8), 901-904.

Gupta, V. K., Luthra, S. K., and Singh, B. P. (2015). Storage behaviour and cooking quality of Indian potato varieties. *Journal of food Science and technology*, *52*(8), 4863-4873

Haase, N. U. (2008). The nutritional value of potatoes in Canada. *J. Potatoes Res*, *50*, 415-417.

Haque, M. M., Islam, M. A., Auyon, S. T., Rahman, M. A., and Marzia, S. (2019). Adaptation practices of climate change in agriculture by the farmers of Phulbari

upazila of Kurigram district in Bangladesh. *Progressive Agriculture*, *30*(3), 253-262

Harrison, B. D. (1958). Studies on the behavior of potato leaf roll and other viruses in the body of their aphid vector Myzus persicae (Sulz.). *Virology*, *6*(1), 265-277.

Heuberger, J. W., and Dimond, A. E. (1941). Relation of flea beetle control to control of Alternaria solani on tomatoes. *Plant Disease Reporter*, *25*, 415-418.

Hide, G. A., and Lapwood, D. H. (1992). Disease aspects of potato production. In *The potato crop* (pp. 403-437). Springer, Dordrecht.

Hims, M. J., and Preece, T. F. (1975). Spongospora subterranea f. sp. subterranea.[Descriptions of Fungi and Bacteria]. *CMI descriptions of pathogenic fungi and bacteria*, (48).

Hooker, W. J. (1981). Compendium of potato diseases, American Phytopathological Society, St. *Paul, MN*.

Hooker, W. J. (1981). *Compendium of potato diseases*. International Potato Center.

Horne, A. S. (1911). On tumour and canker in potato. *Jour. Roy. Hort. Soc*, *37*(362-389), I2.

Horton, D. E., and Anderson, J. L. (1992). Potato production in the context of the world and farm economy. In *The potato crop* (pp. 794-815). Springer, Dordrecht.

Hosny, M., Abo-Elyousr, K. A., Asran, M. R., and Saead, F. A. (2014). Chemical control of potato common scab disease under field conditions. *Archives of Phytopathology and Plant Protection*, *47*(18), 2193-2199.

Hossain, M., Hossain, M. I., Dey, T. K., and Kabir, K. H. (2009). Disease free seed potato production through seed plot technique at farm level. *Annual Report*, *10*.

Islam, M. Z., Islam, M. S., Haque, M. E., Kundu, B. C., and Rahman, M. M. Evaluation of some exotic potato germplasm in northern region of Bangladesh. *Journal of Bioscience and Agriculture Research*, *19*(02), 1652-1657.

Johora, M. F. (2017). *Effect of salinity on morpho-physiological and yield contributing characters of potato (Solanum tuberosum L.)* (Doctoral dissertation, DEPT. OF AGRICULTURAL BOTANY)

Kadiri, O., Olawoye, B., and Oluwajuyitan, T. D. (2021). Potatoes: Processing, Properties, and Application. In *Handbook of Cereals, Pulses, Roots, and Tubers* (pp. 551-568). CRC Press.

Kennedy, J. S., Day, M. F., and Eastop, V. F. (1962). A conspectus of aphids as vectors of plant viruses. *A conspectus of aphids as vectors of plant viruses.*

Khan, M. A., Ullah, O., and Iqbal, J. (2006). Identification of resistant sources against Potato leafroll virus and Myzus persicae Sulz. by biological tests and ELISA. *Pakistan Journal of Phytopathology*, *18*(2), 191-198.

King, S. B., and Alexander, L. J. (1969). Nuclear behavior, septation, and hyphal growth of Alternaria solani. *American Journal of Botany*, *56*(3), 249-253.

Kobayashi, A., Naito, S., Kobayashi, Y. O., Tsuda, S., Ohara-Takada, A., and Mori, M. (2005). Precise, simple screening for resistance in potato varieties to common scab using paper pots. *Journal of General Plant Pathology*, *71*(2), 139-143.

Kostiw, M. (1980). Transmission of potato viruses by some aphid species. *Tag Ber Akad Landwirtsch Wiss DDR, Berlin*, *184*, 339-344.

Kundu, B. C., Kawochar, M. A., Islam, M. S., Goswami, B. K., & Noor, S. (2013). Description of High Yielding Potato Varieties. *Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701, Bangladesh*.

Labruyere, R. E. (1971). *Common scab and its control in seed-potato crops*. Wageningen University and Research.

Lacey, M. J. (2000). *Studies on common scab of potato* (Doctoral dissertation, University of Tasmania).

Lambert, D. H., and Loria, R. (1989). Streptomyces scabies sp. nov., nom. rev. *International Journal of Systematic and Evolutionary Microbiology*, *39*(4), 387-392.

Lapwood, D. H., and Adams, M. J. (1975). Mechanisms of control of common scab by irrigation. In *Biology and Control of Soil Borne Plant Pathogens International Symposium*.

Lawrence, C. H., and McKenzie, A. R. (1981). Powdery scab. *WJ Hooker. Compendium of potato diseases. American Phytopathological Society St. Paul, MN, EE. UU*.

Leiminger, J. H., and Hausladen, H. (2012). Early blight control in potato using disease-orientated threshold values. *Plant disease*, *96*(1), 124-130.

Leiner, R. H., Fry, B. A., Carling, D. E., and Loria, R. (1996). Probable involvement of thaxtomin A in pathogenicity of Streptomyces scabies on seedlings. *Phytopathology (USA)*.

Lorang, J. M., Liu, D., Anderson, N. A., and Schottel, J. L. (1995). Identification of potato scab inducing and suppressive species of Streptomyces. *Phytopathology*, *85*(3), 261-268.

Loria, R., Bukhalid, R. A., Fry, B. A., and King, R. R. (1997). Plant pathogenicity in the genus Streptomyces. *Plant Disease*, *81*(8), 836-846.

Loria, R., Kers, J., and Joshi, M. (2006). Evolution of plant pathogenicity in Streptomyces. *Annu. Rev. Phytopathol.*, *44*, 469-487.

Maiss, E., Brisske-Rode, A., Rusche, A., and Casper, R. (1993). Influence of a coat protein sequence motif on aphid transmission of different plum pox virus (PPV) isolates. In *IXth International Congress of Virology* (p. 349).

Mallick, S. R., Quamruzzaman, A. K. M., Hossain, M. A., Rahman, M. M., Hoque, M. A., and Islam, M. R. (2021). Diversity of Potato Varieties in Bangladesh. *European Journal of Agriculture and Food Sciences*, *3*(3), 56-61.

Mashfiqur, R., Harunor, R., Mustafa, K. S., Al-Arafat, T., Arafat, H., and Sheikh, A. I. N. (2021). Field performance of some potato varieties under different saline conditions of Bangladesh. *African Journal of Agricultural Research*, *17*(11), 1480-1487.

Massalski, P. R., and Harrison, B. D. (1987). Properties of monoclonal antibodies to potato leafroll luteovirus and their use to distinguish virus isolates differing in aphid transmissibility. *Journal of General Virology*, *68*(7), 1813-1821.

Mayo, M. A., Jolly, C. A., Duncan, G. H., Lamb, J. W., and Hay, R. T. (1993). Experimental approaches to determining roles for the proteins in the particles of *PLRV*. *Scottish Crop Research Institute*, 97-100

McKee, R. K. (1958). Assessment of the resistance of potato varieties to common scab. *European Potato Journal*, *1*(1), 65-80.

Mehboob, S., Khan, M. A., Rehman, A., and Idrees, M. (2013). Role of epidemiological and biochemical factors against early blight of potato. *International Journal of Phytopathology*, *2*(1), 08-13.

Mercure, P. (1998). Early blight and late blight of potato. University of Connecticut. *Integrated Pest Management*.

Miyajima, K., Tanaka, F., Takeuchi, T., and Kuninaga, S. (1998). Streptomyces turgidiscabies sp. nov. *International Journal of Systematic and Evolutionary Microbiology*, *48*(2), 495-502.

Mohan, C., and Thind, T. S. (1999). Persistence and relative performance of some new fungicides for effective management of potato late blight in Punjab. *Journal of Mycology and Plant Pathology (India)*.

Monjil, M. S., Nozawa, T., Shibata, Y., Takemoto, D., Ojika, M., and Kawakita, K. (2015). Methanol extract of mycelia from Phytophthora infestans-induced resistance in potato. *Comptes Rendus Biologies*, *338*(3), 185-196.

Morse, W. J. (1914). *Powdery scab of potatoes* (No. 227). Maine Agricultural Experiment Station.

Naher, N., Hossain, M., and Bashar, M. A. (2013). Survey on the incidence and severity of common scab of potato in Bangladesh. *Journal of the Asiatic Society of Bangladesh, Science*, *39*(1), 35-41.

Neergaard, P. (1945). Danish species of Alternaria and Stemphylium. *Danish species of Alternaria and Stemphylium.*

Osborn, T. G. B. (1911). Spongospora subterranea,(Wallroth) Johnson. *Annals of Botany*, *25*(98), 327-341.

Pandey, S.K. (2007) Approaches for Breaching Yield Stagnation in Potato. Potato Journal, 34, 1-9.

Park, D. H., Kim, J. S., Kwon, S. W., Wilson, C., Yu, Y. M., Hur, J. H., and Lim, C. K. (2003). Streptomyces luridiscabiei sp. nov., Streptomyces puniciscabiei sp. nov. and Streptomyces niveiscabiei sp. nov., which cause potato common scab disease in Korea. *International Journal of Systematic and Evolutionary Microbiology*, *53*(6), 2049-2054.

Park, D. H., Kim, J. S., Kwon, S. W., Wilson, C., Yu, Y. M., Hur, J. H., and Lim, C. K. (2003). Streptomyces luridiscabiei sp. nov., Streptomyces puniciscabiei sp. nov. and Streptomyces niveiscabiei sp. nov., which cause potato common scab disease in

Korea. *International Journal of Systematic and Evolutionary Microbiology*, *53*(6), 2049-2054.

Pavlista, A. D. (1996). How important is common scab in seed potatoes?

Ponsen, M. B. (1970). The biological transmission of potato leafroll virus by Myzus persicae. *Netherlands Journal of Plant Pathology*, *76*(4), 234-239.

Powelson, M. L., Johnson, K. B., and Rowe, R. C. (1993). Management of diseases caused by soilborne pathogens. *Potato health management*, 149-158.

Pu, S., Ma, H., Deng, D., Xue, S., Zhu, R., Zhou, Y., and Xiong, X. (2018). Isolation, identification, and characterization of an Aspergillus niger bioflocculant-producing strain using potato starch wastewater as nutrilite and its application. *PloS one*, *13*(1), e0190236.

Qazi, N., Nayeema, J., Qaisar, A., and aadil, A. (2013). Status and symptomatology of early blight (Alternaria solani) of potato (Solanum tuberosum L.) in Kashmir valley. *African Journal of Agricultural Research*, *8*(41), 5104-5115.

Rahman, M. A., Yeasmin, M., Islam, M. A., and Farukh, M. A. (2019). An Empirical Study on Predicting the Wind Speed after Landfall of Tropical Cyclones Over Bay of Bengal. *Journal of Scientific Research in Science and Technology (IJSRST)*, *5*(4), 1-11.

Rands, R. D. (1917). *Early blight of potato and related plants* (No. 42). Agricultural Experiment Station of the University of Wisconsin

Rao, V. G. (1964). The genus Alternaria Nees in Bombay, Maharashtra-II. *Sydowia, Ann. Mycol*, *18*, 65-84.

Rao, V. G. (1969). The Genus Alternaria-from India. *Nova Hedwigia*, *17*(1-4), 219-258.

Raza, W., Ghazanfar, M. U., & Hamid, M. I. (2019). Occurrence of late blight (Phytophthora infestans (Mont) De Bary) in major potato growing areas of Punjab, Pakistan. *Sarhad J. Agric*, *35*, 806-815.

Robert, Y. (1971). Epidémiologie de l'Enroulement de la Pomme de terre: capacité vectrice de stades et de formes des puceronsAulacorthum solani Kltb. Macrosiphum euphorbiae Thomas etMyzus persicae Sulz. *Potato Research*, *14*(3), 130-139.

Robert, Y., and Maury, Y. (1970). Capacités vectrices comparées de plusieurs souches deMyzus persicae Sulz., Aulacorthum solani Kltb. etMacrosiphum euphorbiae thomas dans l'étude de la transmission de l'enroulement de la pomme de terre. *Potato Research*, *13*(3), 199-209.

Rokonuzzaman, M., Rahman, M. A., Yeasmin, M., and Islam, M. A. (2018). Relationship between precipitation and rice production in Rangpur district. *Progressive agriculture*, *29*(1), 10-21.

Rowe, R. C., Miller, S. A., and Riede, R. M. (2021). Early Blight of Potato and Tomato. FactSheet. *Plant Pathology*, 43210-1087.

Schmidt, L., Blanc, S., Cerutti, M., and Louis, C. (1993). Evidence of protein-protein interaction between aphid transmission factor (ATF) and cauliflower mosaic virus (CaMV) particles.

Schulte-Geldermann, E., Gildemacher, P. R., and Struik, P. C. (2012). Improving seed health and seed performance by positive selection in three Kenyan potato varieties. *American Journal of Potato Research*, *89*(6), 429-437.

Schultz, D., and French, R. D. (2009). Early blight potatoes and tomatoes. *Early blight potatoes and tomatoes.*, (PLPA-Pot009-01).

Shaw, D. S., and Khaki, I. A. (1971). Genetical evidence for diploidy in Phytophthora. *Genetics Research*, *17*(2), 165-167.

Shuman, J. L. (1995). *Integrating a host resistance factor into a potato early blight forecasting model* (Doctoral dissertation, Pennsylvania State University).

Sikora, E. (2004). Plant Disease Notes Early Blight of Potato. *Alabama Cooperative Extension System: ANR-1052*.

Simmons, E. G. (2007). *Alternaria: an indentification manual* (No. PA 632.488 S56.).

Singh, B. P., Ahmad, I., Sharma, V. C., and Shekhawat, G. S. (2000). Jhulsacast: a computerized forecast of potato late blight in western Uttar Pradesh. *Journal of the Indian Potato Association*, *27*(1-2), 25-34.

Smith, K. M. (1929). STUDIES ON POTATO VIRUS DISEASES V. INSECT TRANSMISSION OF POTATO LEAF-ROLL. *Annals of applied Biology*, *16*(2), 209-229.

Smith, O. (1968). Potatoes: production, storing, processing. *Potatoes: production, storing, processing.*

Sperling, L. (2008). *When disaster strikes: a guide to assessing seed system security* (No. 363). CIAT

Sprau, F. (1953). Die Bedeutung des Kartoffelschorfes und seine Bekämpfung.

Stamps, D. J. (1985). *Phytophthora infestans*. *CMI Descriptions of Pathogenic Fungi and Bacteria*, (838).

Struik, P. C., and Wiersema, S. G. (1999). *Seed potato technology*. Wageningen Academic Publishers.

Syller, J. (1987). The influence of temperature on transmission of Potato leaf roll virus byMyzus persicae Sulz. *Potato research*, *30*(1), 47-58.

Syller, J. (1994). The effects of temperature on the availability and acquisition of potato leafroll luteovirus by Myzus persicae. *Annals of applied biology*, *125*(1), 141-145.

Sylvester, E. S. (1980). Circulative and propagative virus transmission by aphids. *Annual review of entomology*, *25*(1), 257-286.

Talukder, M. A. H., Rahman, M. S., Haque, Z., Barman, K. K., and Laily, U. K. (2021). Dissemination of BARI released potato varieties in Rangpur region of Bangladesh. *Progressive Agriculture*, *32*(1), 17-21.

Tamada, T., and Harrison, B. D. (1981). Quantitative studies on the uptake and retention of potato leafroll virus by aphids in laboratory and field conditions. *Annals of Applied Biology*, *98*(2), 261-276.

TANAKA, S., and SHIOTA, H. (1970). Latent period of Potato leaf roll virus in the green peach aphid (Myzus persicae Sulzer). *Japanese Journal of Phytopathology*, *36*(2), 106-111.

Van Den Heuvel, J. F. J. M., Verbeek, M., and Peters, D. (1993). The relationship between aphid-transmissibility of potato leafroll virus and surface epitopes of the viral capsid. *Phytopathology*, *83*(10), 1125-1129.

van den Heuvel, J. F. J. M., Verbeek, M., and Van der Wilk, F. (1994). Identification of potato leafroll virus-binding proteins from Myzus persicae(Sulz.). In *Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society (N. E. V.) Amsterdam* (Vol. 5, pp. 195-196).

van den Heuvel, J. F., Verbeek, M., and van der Wilk, F. (1994). Endosymbiotic bacteria associated with circulative transmission of potato leafroll virus by Myzus persicae. *Journal of General Virology*, *75*(10), 2559-2565.

Van der Waals, J. E., Korsten, L., Aveling, T. A. S., and Denner, F. D. N. (2003). Influence of environmental factors on field concentrations ofAlternaria solani conidia above a South African potato crop. *Phytoparasitica*, *31*(4), 353-364.

Van der Zaag, D. E., Asscheman, E., Bokx, J. A., Brinkman, H., Bus, C. B., Hotsma, P. H., ... and Wustman, R. (1996). Potato Diseases, Disease, Pest and Defects. *NIVAA. The Netherlands*.

Vincent, J. R., Ueng, P. P., Lister, R. M., and Larkins, B. A. (1990). Nucleotide sequences of coat protein genes for three isolates of barley yellow dwarf virus and their relationships to other luteovirus coat protein sequences. *Journal of general virology*, *71*(12), 2791-2799.

Wang, A., and Lazarovits, G. (2005). Role of seed tubers in the spread of plant pathogenic Streptomyces and initiating potato common scab disease. *American Journal of Potato Research*, *82*(3), 221-230.

Wanner, L. A., Kirk, W. W., and Qu, X. S. (2014). Field efficacy of nonpathogenic S treptomyces species against potato common scab. *Journal of Applied Microbiology*, *116*(1), 123-133.

Weidemann, H. L. (1982). Zur Vermehrung des Kartoffelblattrollvirus in der Blattlaus Myzus persicae (Sulz.). *Zeitschrift für Angewandte Entomologie*, *94*(1-5), 321-330.

Whitehead, T., McIntosh, T. P., and Findlay, W. M. (1953). Diseases caused by Archimycetes, Actinomycetes and bacteria. *The Potato in Health and Disease, 3rd ed. Oliver and Boyd, Edinburgh*, 367-403.

Wilson, C. R., and Conner, A. J. (1995). Activity of antimicrobial peptides against the causal agents of common scab, black leg, and tuber soft rot diseases of potato.

Wilson, C. R., Pemberton, B. M., and Ransom, L. M. (2001). The effect of irrigation strategies during tuber initiation on marketable yield and development of common scab disease of potato in Russet Burbank in Tasmania. *Potato Research*, *44*(3), 243-251.

Woodford, J. A. T., Jolly, C. A., and Nisbet, A. J. (1994). Effects of aphid feeding behaviour on the transmission of potato leafroll virus. *Annual Report 1994*, 155-9.

Woodford, J.A.T., Jolly, C.A. and Nisbet, A.J. (1994) Effects of aphid feeding behaviour on the transmission of potato leafroll virus. In Annual Report 1994, pp. 155-9. Dundee: Scottish Crop Research Institute.

Yaganza, E. S., Arul, J., & Tweddell, R. J. (2003). Effect of pre-storage application of different organic and inorganic salts on stored potato quality. *Potato research*, *46*(3), 167-178.

Zinnat, K., Hossain, M. S., and Begum, M. M. (2018). Ralstonia solanacearum: a threat to potato production in Bangladesh. *Fundamental and Applied Agriculture*, *3*(1), 407-421.

CHAPTER IX

APPENDICES

Appendix 1. Details of field experiment

1.	Name of Crop	Potato
2.	Variety	Prada, BARI Alu-40, Santana, BARI Alu-79, Innovator, Aluity, Diamant, Carollas, BARI Alu-41, BARI alu-35, BARI alu-37, Queen Anne, Granola, Asterix, Labella, Sunshine, Cardinal, Sagita, and Alkender.
3.	Experimental period	October 2020 – March 2021
4.	Design of Experiment	RCBD
5.	No. of Treatments/Varieties	19
6.	No. of Replication	3
7.	No. of Total Plots	57
8.	Total Plot Size	1021 msq
9.	Individual Plot Size	5×2.5 msq
10.	Plot to plot distance	0.5 m
11.	Block-to-block distance	0.5 m
12.	Border distance	0.5 m
13.	Date of Sowing	November 4, 2020
14.	Date of initiation of disease	December 14, 2020
15.	Date of harvesting	February 3, 2021

Appendix 2. Experiment field and data collection time

Plate 7. Data collection and experimental field, A. Data collection time at early stage, B. Data collection at late period, C. Experimental field site

Appendix 3. ANOVA of % disease infected by early blight at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	571.1	285.53	28.373	4e-08 ***
Variety	18	698.2	38.79	3.855	0.00028 ***
Residuals	36	362.3	10.06		

Appendix 4. ANOVA of % disease severity by early blight at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	21.72	10.860	6.211	0.00482 **

Variety	18	195.47	10.860	6.211	1.76e-06 ***
Residuals	36	62.95	1.749		

Appendix 5. ANOVA of % disease infected by early blight at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	361.4	180.70	8.613	0.000877 ***
Variety	18	1326.3	73.68	3.512	0.000653 ***
Residuals	36	755.3	20.98		

Appendix 6. ANOVA of % disease severity by early blight at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	34.7	17.333	5.005	0.0121 *
Variety	18	462.7	25.706	7.423	1.99e-07 ***
Residuals	36	124.7	3.463		

Appendix 7. ANOVA of % disease infected by early blight at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	244.7	122.37	4.866	0.0135 *
Variety	18	2621.1	145.61	5.791	3.98e-06 ***
Residuals	36	905.3	25.15		

Appendix 8. ANOVA of % disease severity by early blight at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	19.3	9.63	3.712	0.0342 *
Variety	18	908.6	50.48	19.455	2.11e-13 ***
Residuals	36	93.4	2.59		

Appendix 9. ANOVA of % disease infected by late blight at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	97.4	48.68	4.541	0.0174 *
Variety	18	1037.7	57.65	5.377	9.19e-06 ***
Residuals	36	386.0	10.72		

Appendix 10. ANOVA of % disease severity by late blight at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	5.93	2.965	3.992	0.0272 *

Variety	18	75.37	4.187	5.638	5.4e-06 ***
Residuals	36	26.74	0.743		

Appendix 11. ANOVA of % disease infected by late blight at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	160.5	80.26	6.111	0.00519 **
Variety	18	2556.1	142.01	10.813	1.32e-09 ***
Residuals	36	472.8	13.13		

Appendix 12. ANOVA of % disease severity by late blight at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	17.1	8.544	5.887	0.00614 **
Variety	18	370.2	20.565	14.171	2.65e-11 ***
Residuals	36	52.2	1.451		

Appendix 13. ANOVA of % disease infected by late blight at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	277.2	138.60	5.218	0.0102 *
Variety	18	2667.5	148.20	5.580	6.07e-06 ***
Residuals	36	956.1	26.56		

Appendix 14. ANOVA of % disease severity by late blight at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	67.1	33.53	16.55	8.01e-06 ***
Variety	18	464.0	25.78	12.72	1.29e-10 ***
Residuals	36	72.9	2.03		

Appendix 15. ANOVA of % disease infected by *PLRV* at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	8.3	4.14	0.428	0.655
Variety	16	916.0	57.25	5.928	9.97e-06 ***
Residuals	32	309.1	9.66		

Appendix 16. ANOVA of % disease severity by *PLRV* at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	1.10	0.549	0.898	0.417

Variety	16	137.96	8.623	14.100	3.31e-10 ***
Residuals	32	19.57	0.612		

Appendix 17. ANOVA of % disease infected by *PLRV* at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	40	19.91	1.65	0.207
Variety	17	4154	244.34	20.25	5.18e-13 ***
Residuals	34	410	12.06		

Appendix 18. ANOVA of % disease severity by *PLRV* at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	1.4	0.685	0.454	0.639
Variety	17	449.9	26.466	17.542	4.28e-12 ***
Residuals	34	51.3	1.509		

Appendix 19. ANOVA of % disease infected by *PLRV* at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	26	13.0	0.93	0.404
Variety	17	8804	517.9	37.14	<2e-16 ***
Residuals	34	474	13.9		

Appendix 20. ANOVA of % disease severity by *PLRV* at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	33.6	16.80	4.447	0.0192 *
Variety	17	1807.3	106.31	28.149	3.55e-15 ***
Residuals	34	128.4	3.78		

Appendix 21. ANOVA of % disease infected by Scab at harvest

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.7	0.4	0.218	0.808
Variety	5	2710.0	542.0	335.178	8.55e-11 ***
Residuals	10	16.2	1.6		

Appendix 22. ANOVA of % disease severity by Scab at harvest

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.7	0.33	0.923	0.429
Variety	5	847.4	169.48	475.7	1.5e-11 ***
Residuals	10	3.6	0.36		

Appendix 23. ANOVA of Potato plant height (cm) at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	15	7.7	6.634	0.00353 **
Variety	18	5876	326.4	282.153	< 2e-16 ***
Residuals	36	42	1.2		

Appendix 24. ANOVA of Potato plant height (cm) at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	25	12.59	9.236	0.000579 ***
Variety	18	5375	298.60	219.116	< 2e-16 ***
Residuals	36	49	1.36		

Appendix 25. ANOVA of Potato plant height (cm) at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	10	5.2	2.748	0.0775 .
Variety	18	15501	861.2	459.010	<2e-16 ***
Residuals	36	68	1.9		

Appendix 26. ANOVA of Potato plant tillering at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.017	0.0087	2.754	0.0771 .
Variety	18	24.943	1.3857	438.855	<2e-16 ***
Residuals	36	0.114	0.0032		

Appendix 27. ANOVA of Potato plant tillering at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.022	0.0110	2.977	0.0636.
Variety	18	22.517	1.2509	339.754	<2e-16 ***
Residuals	36	0.133	0.0037		

Appendix 28. ANOVA of Potato plant tillering at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.041	0.0203	8.262	0.00111 **
Variety	18	22.908	1.2727	518.982	< 2e-16 ***
Residuals	36	0.088	0.0025		

Appendix 29. ANOVA of Potato plant leaf number at 45 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	39	19.50	18.83	2.53e-06 ***
Variety	18	4676	259.79	250.78	< 2e-16 ***

Residuals	36	37	1.04		

Appendix 30. ANOVA of Potato plant leaf number at 60 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	6	3.1	2.071	0.141
Variety	18	5837	324.3	216.117	<2e-16 ***
Residuals	36	54	1.5		

Appendix 31. ANOVA of Potato plant leaf number at 75 DAS

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	18	9.0	8.859	0.000744 ***
Variety	18	9755	541.9	533.834	< 2e-16 ***
Residuals	36	37	1.0		

Appendix 32. ANOVA of % of tuber in C (<28mm) grade size

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	3	1.4	0.619	0.544
Variety	18	7332	407.3	178.695	<2e-16 ***
Residuals	36	82	2.3		

Appendix 33. ANOVA of % of tuber in B2 (28-44mm) grade size

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	4	2.01	0.124	0.884
Variety	18	4750	263.86	16.223	3.47e-12 ***
Residuals	36	586	16.26		

Appendix 34. ANOVA of % of tuber in B1 (45-55mm) grade size

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	2	0.9	0.442	0.646
Variety	18	9938	552.1	263.869	<2e-16 ***
Residuals	36	75	2.1		

Appendix 35. ANOVA of % of tuber in A (>55mm) grade size

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	0.40	0.200	0.851	0.44
Variety	12	60.10	5.008	21.291	6.59e-10 ***
Residuals	24	5.65	0.235		

Appendix 36. ANOVA of % seed potato tuber (marketable) production

	Df	Sum Sq	Mean Sq	F value	Pr(>F)

Replication	2	3	1.4	1.32	0.28
Variety	18	12179	676.6	658.02	<2e-16 ***
Residuals	36	37	1.0		

Appendix 37. ANOVA of % non-seed potato (non-marketable) production

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	1	0.6	0.591	0.559
Variety	18	12139	674.4	658.811	<2e-16 ***
Residuals	36	37	1.0		

Appendix 38. ANOVA of number of tuber production per hill

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	6.1	3.05	5.423	0.00873 **
Variety	18	690.9	38.38	68.306	< 2e-16 ***
Residuals	36	20.2	0.56		

Appendix 39. ANOVA of weight (g) of tuber production per hill

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Replication	2	81	40	0.494	0.614
Variety	18	1312492	72916	893.640	<2e-16 ***