VARIETAL PERFORMANCE OF WIDELY CULTIVATED SOYBEAN VARIETIES IN BANGLADESH AGAINST MAJOR DISEASES UNDER FIELD CONDITION

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JUNE, 2020

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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: JANUARY-JUNE, 2020

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Dedicated To
My Beloved Parents
And
Respected Teachers

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CERTIFICATE

This is to certify that the thesis entitled "**VARIETAL PERFORMANCE OF WIDELY CULTIVATED SOYBEAN VARIETIES IN BANGLADESH AGAINST MAJOR DISEASES UNDER FIELD CONDITION"** 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 (MS)** in **PLANT PATHOLOGY,** embodies the results of a piece of bona fide research work carried out by **ASHFAKUR RAHMAN**, Registration no.**13-05637** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

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ACKNOWLEDGEMENTS

*Alhamdulillah, all praises are due to the almighty **Allah Rabbul Al-Amin** for his gracious kindness and infinite mercy in all the endeavors the author to let him successfully completes the research work and the thesis leading to Master of Science.*

*The author expresses the deepest sense of respect and heartiest gratitude to his respectable supervisor **Prof. Dr. Fatema Begum**, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for her efficient and scholastic guidance, constructive criticism, valuable suggestions and immense help to carry out the research work toward successful completion and preparation of the thesis by necessary corrections and modification through reviewing the text. Likewise grateful appreciation is conveyed to co-supervisor **Prof. Dr. Md. Belal Hossain,** Department of Plant Pathology, Sher-e-Bangla Agricultural University for constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.*

*The author expresses his deepest respect to **Prof. Dr. Fatema Begum**, Chairman, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for her continuous effort and cooperation throughout the research work, The author is also thankful to the former chairman **Prof. Dr. Md. Belal Hossain** and **Prof. Dr. Khadija Akhter** for their valuable suggestions and untiring effort to complete the research work smoothly.*

*The author expresses his immense respect and indebtedness to **Professor Dr. Md. Rafiqul Islam**, **Professor Dr. M. Salahuddin M. Chowdhury, Professor Dr. Nazneen Sultana, Professor Dr. F. M. Aminuzzaman, Professor Dr. Nazmoon Nahar Tonu, Professor Dr. Abu Noman Faruk, Associate Professor Shukti Rani Chowdhury, Md. Ziaur Rahman Bhuiyan, Hosna Ara Chowdhury Nisha, Syed Mohammad Mohsin** and all other respective teachers of Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, cooperation and encouragement during the entire period of the study.*

*The author wishes to extend his special thanks to Ministry of Science and Technology authority for providing the fellowship to run the research activities smoothly. The author also wants to convey special thanks to **Scientific Officer Towhidi Almas Mujahidi**, BARI, Gazipur.*

The author is deeply grateful to his respectful parents, adorable sister and other relatives for their moral support, encouragement and love with cordial understanding.

The author wishes to extend his special thanks to his class mates and friends specially ***Abdus Samad, Md. Touhudujjaman Anondo, Abu-Bakkar Siddique Antu, Munshi Mohammah Sumon, Anup Kumar Adhikary*** *for their keen help as well as heartiest co-operation and encouragement during experimentation. Special thanks to* ***Samsun Naher, Sadia Kader Oshin*** *for their support and encouragement to complete this study.*

Finally the author appreciates the assistance rendered by the staff members of the Department of Plant Pathology and Central farm, Sher-e-Bangla Agricultural University, Dhaka who have helped her during the period of study.

June, 2020 The Author

VARIETAL PERFORMANCE OF WIDELY CULTIVATED SOYBEAN VARIETIES IN BANGLADESH AGAINST MAJOR DISEASES UNDER FIELD CONDITION

ABSTRACT

The present investigation was initiated to evaluate the varietal performance of soybean varieties against major diseases of soybean in field condition and to determine the disease incidence (%) and percent disease index (PDI) of major diseases of soybean. Four popular varieties namely BARI Soybean-5, Shohag, BINA Soybean-1, BINA Soybean-3 with one Local (OP) varieties were selected. Rust of soybean (*Phakopsora pachyrhizi*), Powdery mildew (*Microsphaera diffusa*), Anthracnose (*Colletotrichum truncatum*) and *Soybean mosaic virus* were considered as the major diseases. The research work was placed in central research field under Plant Pathology department, Sher-e-Bangla Agricultural University, Dhaka during November, 2018 to April, 2019 and the experiment was carried out with Randomized Complete Block Design (RCBD) plot design with three replications. The four major diseases were prevalent on all the soybean varieties though the disease incidence and PDI level varied with the varieties. Among five soybean varieties one (BINA soybean-1) against rust, one (BARI soybean -5) against powdery mildew were found Highly Susceptible, four (BARI Soybean-5, BINA Soybean-3, Shohag, Local) against rust, four (BINA Soybean-3, Shohag, BINA Soybean-1, Local) against powdery mildew, four (BINA Soybean-3, Shohag, BINA Soybean-1, Local) against anthracnose were found Susceptible, four (BARI soybean -5, Shohag, BINA Soybean-1, Local) against soybean mosaic disease, one (BARI soybean -5) against anthracnose were found Moderately Susceptible, One (BINA Soybean-3) was Moderately Resistant against soybean mosaic disease. There were significant reduction of different growth and yield contributing characters due to disease infection among the soybean varieties. The yield of soybean varieties was found negatively correlated with the disease incidence and PDI of major diseases. Considering the disease incidence (%), PDI, growth and yield contributing characters among the soybean varieties it was evident that no resistant variety was found from this investigation, whereas BINA Soybean-1 and BINA Soybean-3 showed appreciable varietal performance against the major diseases.

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LIST OF ACRONYMS

Acronyms	Full form
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
BBS	Bangladesh Bureau of Statistics
et al.	And others
TSP	Triple Super Phosphate
MOP	Muriate of Potash
DAS	Days after sowing
g	Gram
µ g	Microgram
Kg	Kilogram
Cm	Centimeter
No.	Number
%	Percentage
P^H	Potential of Hydrogen
CV(%)	Percentage of coefficient of variance
LSD	Least Significant Difference
V	Variety
0_C	Degree Celsius
RCBD	Randomized Complete Block Design
PDI	Percent Disease Index
NS	Non-Significant
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L.) Merrill) is a leguminous plant, miracle crop of 20th century known as Golden bean. Soybean is a native of North China (Asia) belongs to family *Fabaceae*. It is a versatile and fascinating oil yielding crop with innumerable possibilities of not only improving agriculture but also supporting industries. In the ancient Chinese dictionary named 'Kouangia' which was written about the time of the beginning of the Christian era. Soybean is described as 'Tateon' grand pea. Confucious the great Chinese philosopher in his writings called it as 'Shu' (Kale, 1985). Soybean is not a new crop in Bangladesh although it is still struggling to position itself as an important crop status. During the Colonial Period, the British introduced the soybean to India for use as a forage, green manure and cover crop. In Bangladesh soybeans were first introduced in 1942 (Theodore, 1974)

Soybean provides cholesterol free oil (19.94%) and high quality protein (36.49%). It is a rich source of lysine 7.3% (USDA, 2003). In addition, it contains a good amount of minerals, salts and vitamins (thiamine and riboflavin) and its sprouting grains contain a considerable amount of vitamin C, vitamin A, which is present in the form of precursor carotene. A large number of Indian and Western dishes such as bread, chapati, milk, sweets, pastries etc., can be prepared with soybean (Nagaraj, 2013). Different soya foods like soya milk, soya biscuits, soya chapatti can be prepared from soybean. These crops can fulfill a great part of oil gap in the country. It also has diabetic, medical, industrial and agricultural importance (Hossain *et al*., 1992).

Soybean besides having high yielding potential average worldwide yield was 2.8 ton per hectare (FAOSTAT, 2015). The global production of soybeans is 337 million tones (USDA, 2018). It can be cultivated in both the kharif and rabi seasons in Bangladesh soybean yield is 1.54 ton per hectare and total production is 97000 tones by cultivating almost 63000 hectare of land (BBS,

2017). Bangladesh has to import 1.8 million tons of soybean cooking oil in each year at the cost of more than 1.5 billion USD and soybean meal with about 25.51 million USD per year (Quaiyum *et al*., 2015).

Out of total oil copped area in our country, soybean occupies 62868.31 hectare and production of soybean is 96,921 metric tons (BBS, 2017). This crop can accomplish a great part of oil gap in our country. Char lands of Bangladesh are not suitable for all crops and the nutrient status of char land is poor due to coarse textured soils, low water holding capacity, low nutrient capacity, river bank erosion and frequent flooding (Chowdhury *et al*., 2014). Soybean has the ability to fix atmospheric nitrogen through root nodule bacteria (*Bradyrhizobium japonicum*) and thus it enriches the soil fertility (Mahabal, 1986). It is reported that Bangladesh could meet 40 percent of its soybean oil demand by producing soybean locally (Anon, 2009). The newly recommended improved varieties of soybean have a wide range of maturity and different morphological disparities (Olufajo, 1992; Adeniyan *et al*., 2007; Ahmed *et al*., 2010). Jin *et al*., (2010) observed that the yield increase is correlated with increasing pod number, while seed size and seeds per pod does not change greatly over time.

The crop Soybean has a lot of impending possibility in Bangladesh but in present the production is not sufficient. This is mainly due to use of low yield potential varieties, poor agronomic management practices, climatic conditions, pest concerns and low fertility requirements. It can play a vital role in balancing the protein deficiency of our diet (Mondal, 2001; Rahman, 2003). At present, the domestic oilseed production of Bangladesh is 0.63 million tons, which gives only 0.20 million tons of edible oil and can meet 25-30% requirement (Shaheenuzzamn *et al*., 2014)

Soybean plant health is a critical component of profitable soybean production. The average annual yield losses due to soybean diseases in the United States are approximately 11% (Hartman *et al*., 2015). Plant pathogenic fungi and virus are important groups of organisms that compromise soybean health. Plant

pathogenic fungi are capable of not only reducing yield, but also can modify seed composition so as virus.

A key factor in management of soybean diseases is breeding cultivars that express varying degrees of resistance to specific pathogens. Planting site preparation and planting disease resistant cultivars are common options to manage soybean diseases (Grau *et al*., 2004). Soybean is known to suffer from more than 100 pathogens among the diseases like rust of soybean caused by (*Phakopsora pachyrhizi*), powdery mildew of soybean (*Microsphaera diffusa*), Anthracnose *(Colletotrichum truncatum),* Root rot (*Rhizoctonia* sp), Aerial Blight *(Rhizoctonia bataticola),* Pod blight (*Alternaria* sp) Leaf Spot (*Alternaria* sp.), Target Leaf Spot *(Corynespora cassiicola), Cercospora* Leaf Spot *(Cercospora kikuchii),* Bacterial Pustule (*Xanthomonas campestris* pv. *glycines), Soybean mosaic virus* and *Yellow mosaic virus* (Singh and Shrivastava, 2007). These diseases causes considerable yield losses, 10-90% by rust (Bromfield,1984; Sinclair,1989), 16-100% by anthracnose (Backman *et al*., 1985; Sinclair, 1989), 10-35% by powdery mildew (Sinclair, 1989), *Soybean mosaic virus* may cause significant yield losses reaching in some cases as high as 94% of the total yield. Infection of plants at an early stage results in reduction of pod set, reduction in seed size and weight, increase in seed coat mottling and decrease in seed quality. Late infection with *Soybean mosaic virus*, however, has a limited effect on yield and seed quality (Hill *et al*., 1987).

Even though many options are there for the management of these diseases such as cultural, chemical and biological methods; host plant resistance is the best, because of its eco-friendly nature and cost effectiveness. In the host plant resistance, multiple disease resistance is more important and desirable too, as they reduce losses caused by more than one disease. Identification of multiple disease resistant sources is also important as they can be utilized in breeding for multiple disease resistance.

In this context, present investigation was undertaken with the following objectives:

- To evaluate the varietal performance of soybean varieties against major diseases of soybean in field condition
- To determine disease incidence (%) and percent disease index (PDI) of major diseases of soybean

CHAPTER II

REVIEW OF LITERATURE

Soybean is an important oil seed crop in the world. It is being used for nutritional, industrial and medicinal purposes. It is also called as wonder crop of the world. On the contrary, to this, foliar diseases are threatening to the crop. They directly cause the yield loss or affect the quality of the seeds. As a management strategy use of multiple disease resistant genotypes usage plays a major role in reduction of losses caused by diseases. Availability of literature pertaining to multiple disease resistant genotypes in soybean is not very rich. Hence in this chapter an attempt was made to compile the relevant reviews for the present investigation.

2.1 Origin and nutrition soybean

Qiu and Chang (2009) stated that Soybean (*Glycine max* L. Merr.) is a leguminous crop and a good source of protein and vegetable oil. It can play a vital role in balancing the protein deficiency of our diet. The high level of plant-based protein contained in these legumes is safe for people's health.

Sobko, *et al*. (2020) stated that Soybean (*Glycine max* L. Merrill) is considered a globally strategic crop because it has become the main supplier of plant oil and protein.

Singh (2010) stated that Soybean can supply up to 80% of its nitrogen needs through symbiosis with rhizobia and subsequent fixation of N_2 from the air.

2.2 Screening of soybean genotypes against different diseases

Chandra *et al*. (1987) reported that among 722 soybean entries tested under conditions of natural infection by *Phakopsora pachyrhizi* and *Cercospora sojina*, only two entries are resistant for both the diseases.

In AVRDC, Taiwan, selected a total of 116 soybean accessions for high yield from the progeny of 20 crosses, were screened in the field for resistance to *Perenospora manshurica* (natural infection) and *Xanthomonas phaseoli*

var.*sojense* (by artificial inoculation) and found that 11 accessions as moderately resistant (Anon., 1988).

Patil *et al*. (2004) screened 1200 soybean genotypes to rust during *kharif* 2002 and 2003 and 36 soybean genotypes against yellow mosaic during *rabi*/summer 1998-99 at Dharwad, Sankeshwar and Nippani regions of Karnataka, India. Out of 1200 genotypes screened against rust, only two genotypes EC-241778 and EC-241780 are reported as highly resistant and six genotypes, EC-241760, EC-333917, EC-325115, EC-251378, EC-389149 and EC- 432536 moderately resistant and all the remaining genotypes as susceptible to highly susceptible. Among the 36 genotypes screened against yellow mosaic, one genotype, DSb-4 was reported to be completely free from yellow mosaic.

Shrirao *et al*., (2009) conducted an experiment on 16 genotypes against major diseases of Soybean, 4 entries were shown Highly Resistant, 3 were shown Moderately Resistant reaction to *Rhizoctonia* Root Rot an *Rhizoctonia* aerial blight disease, while in case of Pod Blight disease, 13 entries were shown Highly Resistant, and biotic entry shown Moderately Resistant reaction, 4 entries were shown Absolutely Resistant, 12 entries were shown highly resistant reaction to Anthracnose disease.

Balgude *et al.* (2012) studied various strains and isolates of SMV that cause different symptoms on soybean have been identified worldwide. Common symptoms of infection by SMV on soybean include mosaic and mottling, crinkling of leaves, leaf puckering, dwarfing and top necrosis.

2.3 Soybean Rust (*Phakopsora pachyrhizi* Syd)

2.3.1 Symptomatology

Singh (1973) stated that Soybean rust caused by *Phakopsora pachyrhizi* is one of the most destructive fungal diseases of soybeans causing serious growth and yield losses. Studies on symptomatology morphology, pathogenicity, survival of the fungus, and suitable control measure of the diseases.

Bromfield (1978) conducted a review of the occurrence and symptomatology of soybean rust (*Phakospora pachyrhizi*), its morphology and taxonomy, disease detection, epidemiology and breeding for resistant soybean varieties are discussed.

Yeh (1983) showed soybean rust is the major disease of soybeans in Taiwan in spring and fall. General symptoms of the disease, the physiological effect on the plant, and the dissemination of the pathogen are discussed. Without fungicide yield may be reduced 20-50 (%).

2.3.2 Reaction of soybean genotypes against rust

Lantican (1977) reported that, PI-200492 was the main source of resistance for soybean rust, which was used in Taiwan to develop resistant cultivars K-3, T-3 and T-4. Cultivars reported as highly resistant in Australia and India but were found susceptible in the Philippines. Cultivars, which did show resistance when first introduced into Philippines such as TK-5, Wayne, K-3, T-3, T-4 and PI series have all gradually lost their resistance.

Bromfield and Melching (1982) identified specific resistant sources to soybean rust pathogen. Each of the three soybean accessions, PI-200492, PI-230970 and PI-462312 (Ankur) carries a dominant gene governing specific resistance to *P. pachyrhizi*.

Vale *et al*. (1985) evaluated 34 Brazilian soybean cultivars against rust, out of which none was immune to rust infection but Mineira, Vila Rica, FT-1, IVA-1, IAC-4, BR-4 and Uniano were rated as resistant with <50 per cent sporulating uredia and a severity index of one even after 15 days. Development of rust was

very slow on Santa Rosa compared to the susceptible Parana under field conditions.

Hartwig, (1986) studied in detail and identified gene-conferring resistance to soybean rust. The soybean genotypes PI-200492, PI-230970 and PI-462312 each carried a single dominant gene conferring resistance to specific isolate of rust pathogen.

Koch *et al*. (1987) conducted pot and field tests in northern Thailand in 1983, the most resistant soybean accessions were the lines 072 and 113 which showed RB (reddish brown) lesions after the inoculation of young plants with *P. pachyrhizi* Syd. Based on yield loss, disease progress and the number of uredia/lesion, SJ-1 was the most susceptible producing TAN lesions.

Hartman *et al*. (1991) inoculated *P.pachyrhizi* on two soybean genotypes at three different reproductive growth stages (GS) in four trials. Rust was more severe on Taifa Kaohsiung No.5 (TK-5), a commercial cultivar, than on SRE-B15-A (B15A). At GS R6, the rust infection was ranged between 14 to 95 per cent on TK-5 and 0 to 34 per cent on SREB15-A (B15A).

Hartman *et al*. (1992) evaluated 294 accessions representing 12 perennial *Glycine spp*. for resistance to *P. pachyrhizi* and found that 23 per cent of these were resistant, 18 percent were moderately resistant and 58 per cent were susceptible.

Ramteke *et al*. (2004) conducted an experiment during the rainy season of 2002 and 2003 to screen 41 genotypes of soybean [*Glycine max* (L.) Merrill] against rust under field condition at rust hot spot Ugar-Khurd, Belgaum district, Karnataka and found none of the genotypes as resistant including seven differentials (PI-200492, PI-230970, Ankur, PI-462312, PI-459025, PI-230971 and PI-459024) which were reported earlier as resistant.

An experiment was conducted by Verma *et al.* (2004) to evaluate 242 germplasm lines/cultivars of soybean under natural epiphytotic conditions for resistance to rust and reported only one line *i.e*., SJ-1 as highly resistant, three

lines *viz*., JS-19, RPSP-728, PK-838 as resistant, 16 lines as moderately resistant and rest were either susceptible or highly susceptible.

2.4 Powdery mildew of soybean (*Microsphaera diffusa* Ke. and Pk.)

2.4.1 Symptomatology

Phillips (1984) said that Reactions of soyabean cultivars to *M. diffusa* isolates collected in 1973, 1979 and 1982 indicated no change in the pathogen strain. in Ganus. during this 9-yr period despite extensive planting of resistant cultivars and regular occurrence of the sexual stage of this fungus.

An experiment done by Lohnes and Bernard (1992), they showed that reaction of soybeans to powdery mildew (*Microsphaera diffusa*) has been reported to be regulated by a single gene pair Rmd rmd, with the dominant allele Rmd activating adult-plant resistance and rmd causing susceptibility.

Gonçalves *et al*. (2002) stated that resistant and susceptible soybean cultivars were performed and the F 2 populations were obtained to study the inheritance of soybean resistance to powdery mildew .The reaction to powdery mildew was studied in a greenhouse and pots carrying plants with symptoms were distributed.

2.4.2 Reaction of soybean genotypes against powdery mildew

Grau and Laurence (1975) observed the resistance and heritability of resistance to powdery mildew of soybean.

Buzzell and Haas (1978) in glasshouse tests with *M. diffusa* repeated that adult plant resistance was found to be governed by a dominant gene, proposed as *Rmd*, with the recessive allele, *rmd*, resulted in susceptibility at all stages.

An experiment was conducted by Mignucci and Lim (1980) powdery mildew (*Microspraera diffusa*) development on soybeans with adult-plant resistance.

Tanaka *et al.* (1993) studied three greenhouse grown soybean cultivars in Brazil, among them Hampton was the worst affected by powdery mildew (*M. diffusa*), followed by IAC-Foscarin 31 and IAC Santa Maria 702.

Banniza *et al*. (2004) first recorded powdery mildew on lentil in Canada.

Almeida, *et al*. (2008) stated that soybean powdery mildew (*Erysiphe diffusa*) was considered a minor disease in Brazil in the decades immediately after its identification. However, since the outbreak in 1996/97 in all cultivated areas the disease has become a constant threat to farmers and losses of up to 25% have been reported.

An experiment set by Attanayake *et al*. (2009) stated that the taxonomy of the powdery mildew fungus infecting lentil in the Pacific Northwest (PNW) of the United States was investigated on the basis of morphology and rDNA internal transcribed spacer (ITS) sequences. Anamorphic characters were in close agreement with descriptions of *Erysiphe trifolii.*

Attanayake, *et al*. (2010) investigated using both molecular and morphological techniques. Phylogenetic analyses based on rDNA ITS sequences, in combination with assessment of morphological characters, defined two groups of powdery mildews infecting pea.

McTaggart, *et al*. (2012) stated two powdery mildew fungi with *Pseudoidium anamorphs* are considered pathogens of Glycine, namely *Erysiphe diffusa* (Cooke & Peck) U. Braun & S. Takam and *E. glycines*, FL Tai (Braun and Cook 2012). A third species, *E. pisi*, DC, has a broad occurrence on hosts in the *Fabaceae* worldwide.

Carmona *et al*. (2015) studied on the use of foliar fungicides is a common disease control practice among soybean producers around the world, yet there is still no clear understanding about the timing and opportunity of fungicide applications to manage late season diseases (LSD) in soybean crops. The unnecessary use of fungicides in extended areas increases production costs, risk of resistance and risk of negative environmental impact.

2.5 Anthracnose of soybean *Colletotrichum truncatum* (Schw.) Andrus and Moore.

2.5.1 Symptomatology

Verma and Upadhyay (1973) reported that the incidence of pod blight and stem dieback caused by *Colletotrichum dematium* var. *truncatum* was higher in var. Clarke-63 than in Bragg.

Sij *et al*. (1985) Davis' soybean plants were planted in four-row. Second harvest anthracnose ratings were taken for only 2 year (1979 and 1980). Symptoms of anthracnose on which the ratings were based were large, irregular-shaped black acervuli on pods and stems of mature plants.

Dias *et al*. (2016) stated that when applications of fungicides are carried out after symptoms appear, there is no reducing Anthracnose of soybeans. First report on *Colletotrichum chlorophyti* caused anthracnose of soybean.

Agam *et al*. (2019) studied on isolation, pathogenicity, symptomatology and control measures in vitro on anthracnose of soybean *Colletotrichum truncatum*, the cause of anthracnose disease of soybean.

2.5.2 Reaction of soybean genotypes against anthracnose

Chacko and Khare (1978) screened 47 varieties of soybean under field conditions by artificial inoculation to identify the source of resistance against anthracnose. Observations were recorded 15 days after inoculation on the basis of leaf area infected. They reported that only variety Kalitur as resistant and PK 72-92 as moderately resistant.

Khare and Chacko (1983) screened 26 soybean varieties against anthracnose. The disease index was ranged between 0 to 58.2 per cent. Five varieties *viz*., Kalitur, EC-14437, Lee, N-67 and EC-2586 were found to be completely free from disease under field condition.

Manandhar *et al*. (1985) evaluated 200 soybean cultivars under controlled conditions. They found that plants were susceptible at all growth stages and

early infection lead to death of the seedlings. Only two varieties (Tarheel and PI 95-860) were found resistant to this disease.

Manandhar *et al*. (1988) tested 414 germplasm lines under controlled conditions and for this they planted five seeds of each line and artificially inoculated with conidial suspension of *C. truncatum*. They observed none of the germplasm lines were completely free from the disease.

Singh (1990) evaluated relative resistance in soybean cultivars to pod blight caused by *C. truncatum* during the rainy season of 1990 at Indore and found only two cv. HM-1 and Birsa soybean-2 as resistant. Rest of the cultivars showed high pod blight under field conditions.

Kaushal and Paul (1991) screened 331 local and exotic soybean cultivars under severe natural infection by *Colletotrichum dematium* in the Kangra valley, Himachal Pradesh and recorded 18 cultivars as moderately resistant (up to 10% disease incidence), 146 as moderately susceptible, 150 as susceptible and 17 as highly susceptible.

Work carried out at AVRDC, Taiwan by Anon., (1992) for the evaluation of soybean lines against anthracnose revealed that only five lines *viz*., AGS-18, 128, 138, 139 and 151 recorded severity index below three and hence were classified as resistant.

Shirshikar (1995) screened 42 cultivars of soybean and found none of the cultivars as either immune or highly resistant to the anthracnose disease. Twenty-one cultivars showed susceptible reaction and 19 were found highly susceptible. One cultivar *i.e.*, NRC-1 was found moderately resistant and cultivar Durga showed resistant reaction.

Ghawde *et al*. (1996) conducted a field experiment at the College of Agriculture, Nagpur, India to evaluate seven varieties against *C. truncatum* under artificial epiphytotic conditions. Varieties JS 22 and PKV 1 were found highly resistant and MACS 3 showed resistant reaction.

Madhusudhan (2002) made an attempt to evaluate 60 soybean genotypes against *C. truncatum* under glass house condition with artificial inoculation. He reported only three genotypes *viz*., PK-1129, DSb-2 and Cockstaurt as resistant and 27 genotypes as moderately resistant and remaining genotypes as susceptible to highly susceptible.

Kulkarni (2009) conducted a roving survey during *Kharif* 2006 and 2007 in eleven major green gram growing districts of northern Karnataka. The results revealed that during 2006 anthracnose of green gram was noticed in the range of 21.36 to 58.97 per cent and during 2007, the disease severity noticed in the range of 24.67 to 60.07 per cent.

Sajeesh (2014) studied the seed health testing of different soybean cultivars from different parts of northern Karnataka, the cv. JS 335 in Dharwad has showed maximum per cent seed infection (8%) of *C. truncatum* followed by 2 and 1 in cv. DSb 1 and DSb 21 respectively. There was no seed infection of *C. truncatum* in samples collected from Gokak region on cv.JS 335.

2.6 *Soybean mosaic virus* (SMV)

2.6.1 Symptomatology

Kiihl and Hartwig (1979) described the symptoms of soybean mosaic were first described by Clinton (1) in 1916 and the virus nature of the disease was established by Gardner and Kend- rick (3) in 1921. Conover (2) in 1948 verified that the mosaic of soybeans.

Hunst and Tolin (1982) described two SMV isolates and compares their host range, symptomatology, serology which induces mild symptoms on one cultivar (Essex) and severe symptoms on another (Electron microscopy of soybeans infected with two isolates of soybean mosaic virus).

Li, *et al*. (2010) said that Soybean mosaic virus spread by aphids, resulting in early infection and more severe disease symptoms in the later stage Conover (7) first recognized that soybean mosaic disease was caused by more than one strain of SMV. In the United States and Korea, the same set of soybean differentials was identified.

2.6.2 Reaction of soybean genotypes against *Soybean mosaic virus* (SMV)

Roane *et al*. (1986) suggested a gene for gene model for the SMV-soybean interactions. Inheritance studies of SMV resistance in soybeans were the basis for assigning the different Rsv1, Rsv2, and Rsv3 gene symbols.

Akhtar *et al*. (1992) screened twelve varieties for resistance to SMV. Four varieties (Crow ford, Cico, Zane and 80-B- 4007) were found resistant to the virus.

Steinlage *et al*. (2002); Hill *et al*. (1980); Halbert *et al*. (1981); Jagtap *et al*. (2011) reported that the transmission of SMV occurs in soybean fields because not only does the virus spread from parent to progeny, it also spreads via the movement of more than 30 different kinds of aphid species, which may lead to secondary spreading of the virus.

Zheng *et al*. (2003) found that soybean line 'ICGR95-5383', a newly released germplasm from China, is resistant (R) to soybean mosaic virus (SMV). In

under to investigate the inheritance of SMV resistance ICGR95-5383 was crossed to the susceptible (S) cultivars 'HB 1', 'Tiefeng21', 'Amsoy', and 'Williams'.

Soybean mosaic virus (SMV) is considered to be one of the most significant soybean viruses recurring worldwide (Bos, 1972). Economic loss caused by SMV typically ranges between 8%-35% and in severe case may reach up to 100% (Ahangaran *et al.*, 2009)

Seo *et al*. (2009) Cho and Goodman (1979), Steinlage *et al*. (2002), Hobbs *et al*. (2003) and Gunduz *et al*. (2004) said that in particular, infected soybean by SMV, plants may result in yield losses because of the noticeable reduction in the number of seeds produced by infected plants.

Shrirao *et al*. (2009) evaluated 16 genotypes and reported that 14 entries were found absolutely resistant against soybean mosaic virus and two showed highly resistant reaction against SMV.

Bachkar *et al*. (2019) conducted a study in view to check the infectivity of soybean mosaic virus on soybean plants under natural and glass house conditions where 36 genotypes were screened. Field screening of soybean genotypes revealed that out of thirty six genotypes two were resistance (PS-1589 and PS-1587), while seven were moderately resistant (RVS- 2009-09, AMS-MB-5-19, SL-1104, MASC-1520, RSC-10-70, SL-1113 and JS-9305) to SMV under field conditions.

2.7 Assessment of yield loss

Mousanejad *et al*. (2010) stated that assessment of yield loss was carried out mainly based on yield comparisons between infected and healthy plants or between plants with different disease severities using field plots. Percent yield loss (%YL) in terms of grain weight was calculated.

Higley (1988) conducted a study on Brown stem rot (BSR), caused by *Phialophora gregata*, is a vascular disease of soybean. Symptoms include browning of vascular tissue and pith, and interveinal chlorosis and necrosis in

leaves. Effects of BSR on soybean water relations, photosynthesis, growth, and yield were evaluated using a resistant (BSR 201) and a susceptible (Pride B216) cultivar.

Mueller *et al*. (2009) observed that soybean rust, caused by *Phakopsora pachyrhizi*, is a devastating foliar disease of soybean that may cause significant yield losses if not managed by well-timed fungicide applications. To determine the effect of fungicide timing on soybean rust severity and soybean yield, field trials were completed in Paraguay, the United States and Zimbabwe

2.8 Works done in Bangladesh

A study was conducted in the Microbiology Laboratory of Plant Pathology Department, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur by Shovan *et al*. (2008) during 2005 to 2006 to control *Colletotrichum dematium* causing anthracnose of soybean with fungicides, plant extracts and *Trichoderma harzianum*.

Hossain and Yamanaka (2019) studied on Asian soybean rust (ASR) caused by *Phakopsora pachyrhizi* is estimated to cause massive yield losses in Bangladesh. For understanding its population structure to guide deployment of durable resistance in soybean germplasm against all pathogen populations, 13 *P. pachyrhizi* strains collected from Lakshmipur, Noakhali and Bhola Districts in Bangladesh in 2016 were evaluated for pathogenicity on 12 soybean differentials. The tested strains had both identical and dissimilar pathogenicity profiles.

Akhter *et al*. (2019) studied on plant virus diseases are significant constraints in agricultural production in Bangladesh. The hot and humid environmental conditions are highly favorable for the perpetuation of the viruses as well as vectors round the year. Although, the virus diseases are recorded in many crops, vegetables and pulses are most seriously affected.

CHAPTER III

MATERIALS AND METHODS

A field experiment was undertaken at the central research field, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2018 to March 2019. This chapter contents with a concise description on experimental site, climate, soil and land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Geographical location of the experimental site

The present piece of research work was placed in the central research field under Department of Plant Pathology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the site is 23°74'N latitude and 90°35'E longitude with an elevation of 8.2 meter from sea level (Anon., 2004).

3.2 Agro-Ecological Region of the experimental site

The experimental field belongs to the agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where flood plain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as "islands" surrounded by floodplain (Anon., 1988b). The experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.3 Characteristics of Soil

The soil of the experimental area was loamy belonging to the Madhupur Tract under AEZ 28. The soil of the experimental plots were clay loam, land was medium high with medium fertility level (Appendix II).The organic matter and nitrogen status of the soil was poor. The pH varied from 6.00-6.63.

3.4 Weather condition of the experimental site

The climate of the experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-

monsoon period or hot season from March to April and the monsoon period from May to October. The experiment was conducted during November 2018 to March 2019 (Appendix III)

3.5 Planting Material

For fulfilling the objective of the experiment five soybean varieties were selected as a planting materials. They were

- BARI Soybean-5
- BINA Soybean-3
- Shohag (PB-1)
- BINA Soybean-1
- Local (OP)

3.6 Collection of the varieties

Variety	Source
BARI Soybean-5 (V_1)	Bangladesh Agricultural Research Institute (BARI), Gazipur
BINA soybean-3 (V_2)	Bangladesh Institute of Nuclear Agriculture(BINA), Mymensingh
Shohag (PB-1) (V_3)	Bangladesh Agricultural Research Institute (BARI), Gazipur
BINA soybean-1 (V_4)	Bangladesh Institute of Nuclear Agriculture(BINA), Mymensingh
Local (OP) (V_5)	Noakhali, Bangladesh

3.7 Land preparation

The land of the experimental site was first opened in November 2018 with power tiller. Later on, the land was ploughed and cross-ploughed three times followed by laddering to obtain the desired condition. The corners of the land were spaded and larger clods were broken into smaller pieces after ploughing and laddering all the stubbles and uprooted weeds were removed and the land was ready.

3.8 Design and layout of the experiment

The experimental land was carried out with Randomized Complete Block Design (RCBD) plot design with three replications. An area of 13.5 m × 15.5 m was divided into three rows. The total Number of plots was 15. The size of each unit plot was 4 m × 1.5 m. The space between two adjacent replications was 0.75 m. The space between two adjacent rows was 0.5 m. The layout was done at 27 November, 2018.

3.9 Fertilizer application

Fertilizer was applied following the recommendations (Krishi Projukti Hatboi) of Bangladesh Agricultural Research Institute (BARI, 2019) during final land preparation. Doses were calculated for the land area 13.5 m × 15.5 m. All fertilizers were applied during final land preparation.

Fertilizer	Doses (kg)
Urea	1.25
TSP	3.66
MOP	2.51
Gypsum	2.40
Boron	0.20

3.10 Soybean seed sowing

The soybean seeds were sown in rows by line sowing system maintaining row to row distance 30 (cm) on 28 November, 2018.

3.11 Intercultural operations

3.11.1 Thinning

Seeds were germinated 10 days after sowing (DAS). After germination thinning was done two times; first thinning was done at 20 DAS and second was done at 40 DAS to obtain proper plant population in each plot plant to plant distance 5-6 (cm) was maintained.

3.11.2 Irrigation and drainage

Irrigation was done at 15, 35 and 70 DAS.

3.11.3 Weeding

The crop field was weeded three times; first weeding was done at 15 DAS and second at 35 DAS and last one was done at 70 DAS.

3.12 Data collection

Five plants from each variety were randomly selected and tagged for every major disease (Plate 1). The collected parameters during field experiments were

- Number of healthy plants
- Number of infected plants
- Leaf area infection (%)
- Plant height (cm)
- Number of leaves
- Number of branches
- Number of pods/plant
- Number of seeds /pods
- 100 seed weight (g)
- Yield/plot (kg)
- Yield (ton/ha)

Plate 1: Diseased plants tagged with colored tap

3.13 Visual identification of major diseases of soybean

Soybean suffer from more than 100 pathogens causing the diseases, among them Rust of soybean (*Phakopsora pachyrhizi*), Powdery mildew of soybean (*Microsphaera diffusa*), Pod blight and Anthracnose *(Colletotrichum truncatum), Soybean mosaic virus* (Singh and Shrivastava, 2007) are considered as major diseases.

3.13.1 Symptoms of rust of soybean

Rust of soybean caused by *Phakopsora pachyrhizi* and *P. meibomiae* (mild pathogen). The following symptoms were recorded that are identical to rust of soybean (Plate 2)

Symptoms begin on leaves in the lower plant canopy. Tan or reddish-brown lesions (spots) develop first on the underside of leaves. Small pustules (blisters) develop in the lesions, which break open and release masses of tan spores (Singh, 1973 and Bromfield, 1978).

A **B** **C**

Plate 2: Diagnostic symptoms of rust of soybean in leaf

(A) Rust infection at early stage, (**B**) Severe diseased condition of leaf,

(C) Rust pustules on the ventral side of leaf

3.13.2 Symptoms of powdery mildew of soybean

Powdery mildew of soybean is caused by the fungus *Microsphaera diffusa*. Initially identified as *Erysiphe polygoni*, *M. diffusa* is now accepted as the cause of soybean powdery mildew. The following symptoms were recorded that are identical to powdery mildew of soybean (Plate 3)

Common signs of powdery mildew are white powdery patches of fungal mycelium and conidia forming on the upper surface of soybean leaves, cotyledons, stems and pods. Initially, the patches are small and later grow in size and coalesce to form larger whitish area. Usually, the presence of white powdery patches on plant surface is enough to diagnose powdery mildew of soybean (Mignucci, *et al*., 1980).

A **B** **C**

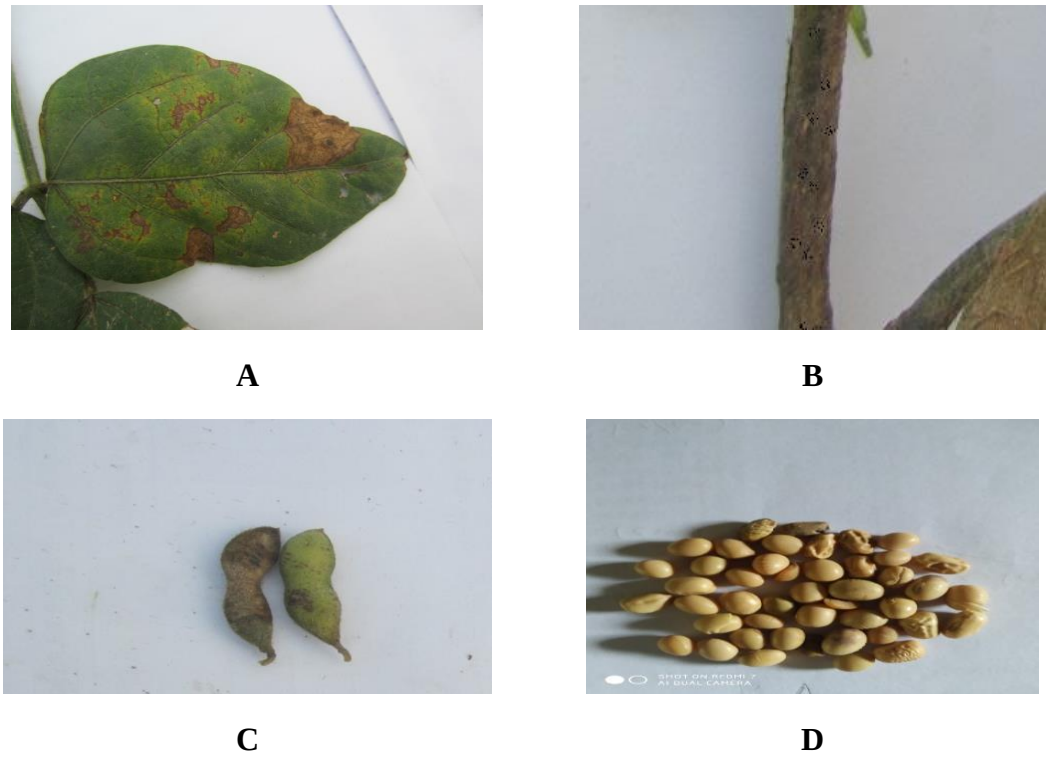
Plate 3: Diagnostic symptoms of powdery mildew of soybean
(A)White patches at early stage, (**B**) White patches at severe stage of infection, **(C)** Infected pod with infected twig

3.13.3 Symptoms of anthracnose of soybean

The primary pathogen that causes anthracnose is the fungus *Colletotrichum truncatum*. The following symptoms were recorded that are identical to anthracnose of soybean (Plate 4)

Infected leaves may develop brown veins and curl up. Irregular brown spots develop in a random pattern on stems and pods. Brown cankers can appear

on petioles and cause defoliation. Infection of pods results in few or small seeds per pod. Infected seeds may have no symptoms or may develop brown or gray areas with black specks (Sharma, *et al*., 2011 and Mahmodi, *et al*., 2013).



A **B**

C **D**

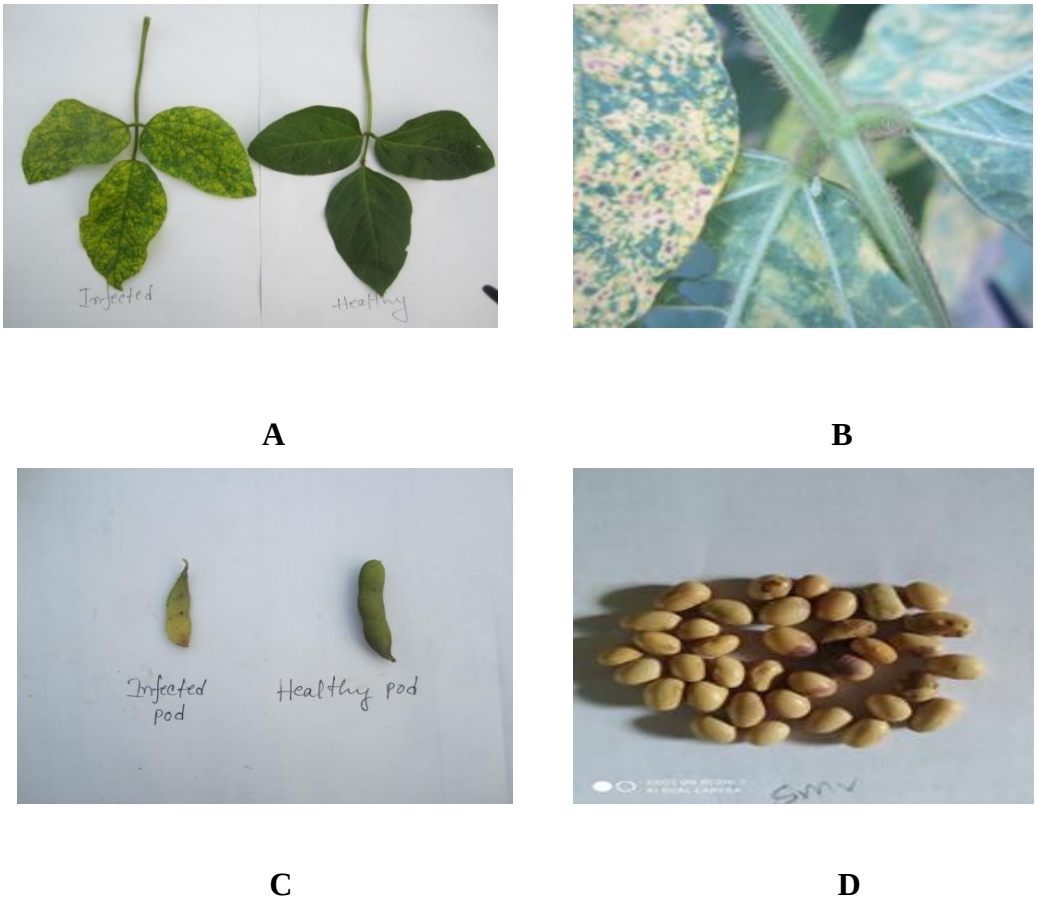
Plate 4: Diagnostic symptoms of Anthracnose of soybean
(A) Irregular brown spot on leaves, (**B)** Infected stem, **(C)** Infected pods, (**D)** Seeds of infected pods

3.13.4 Symptoms of Soybean mosaic disease

Soybean mosaic virus (SMV) occurs widely SMV can cause yield loss, affect seed quality, and reduce seed germination and nodulation. The following symptoms were recorded that are identical to SMV of soybean (Plate 5)

Symptoms of plants infected with *Soybean mosaic virus* can range from no apparent symptoms to severely mottled and deformed leaves. Mottling appears as light and dark green patches on individual leaves. Symptoms are most obvious on young, rapidly growing leaves. Infected leaf blades can become puckered along the veins and curled downward. Common symptoms

of infection by SMV on soybean include mosaic and mottling, crinkling of leaves, leaf puckering, dwarfing and top necrosis (Balgude *et al.* 2012).



A **B**

C **D**

Plate 5: Diagnostic symptoms of soybean mosaic disease

(A) Infected leaf at early stage, (**B**) Infected leaf at later stage with vector, (**C**) Infected pod and healthy pod, (**D**) Seeds of infected plants

3.14 Disease incidence (%)

Disease incidence (%) of major diseases of soybean measured under natural infection by using the following formula (Waller *et al*., 2002).

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \text{ x } 100$$

3.15 Percent disease index (PDI)

Percent disease index (PDI) calculated by using the formula given by Wheeler (1969).

$$\text{Percent disease index (PDI)} = \frac{\text{Sum of individual disease ratings}}{\text{Total No. of observations x Maximum disease rating}} \times 100$$

3.15.1 Scale for Soybean rust disease

The percent disease index (PDI) of rust on genotypes was scored at 75 DAS (Nagaraj, 2013) based on percent leaf area infected by using the scale given by Mayee and Datar (1986).

Rating	Reactions	Description
1	Immune (I)	No Symptoms
3	Highly resistant (HR)	1-10% leaf area covered with rust pustules
5	Resistant (R)	11-25% leaf area covered with rust pustules
7	Susceptible (S)	26-50% leaf area covered with rust pustules
9	Highly susceptible (HS)	>50% leaf area covered with rust pustules

3.15.2 Scale for Powdery mildew of soybean

The observations for percent disease index (PDI) were recorded, based on the per cent leaf area infected at 85 DAS (Nagaraj, 2013) by using the scale given by Mayee and Datar (1986) which is furnished below

Rating	Reactions	Description
0	Highly resistant (HR)	No Symptoms
1	Resistant (R)	<1% leaf area covered with powdery growth
3	Moderately Resistant (R)	1-10% leaf area covered with powdery growth
5	Moderately susceptible	11-25% leaf area covered with powdery growth
7	Susceptible (S)	26-50% leaf area covered with powdery growth
9	Highly susceptible (HS)	>50% leaf area covered with powdery growth

3.15.3 Scale for Anthracnose disease of soybean

The observations for percent disease index (PDI) were recorded, based on the % leaf area infected at 85 DAS (Nagaraj, 2013) by using the scale given by Manandhar *et al*. (1988) and Wheeler (1969).

Rating	Reactions	Description
0	Immune (I)	No of lesions / discolouration
1	Resistant (R)	1% area covered with lesions
3	Moderately Resistant (R)	1.1-10% area covered with lesions
5	Moderately Susceptible (MS)	10.1-25% area covered with lesion
7	Susceptible (S)	25.1-50% area covered with lesions
9	Highly Susceptible (HS)	>50% area covered with lesions

3.15.4 Scale for soybean mosaic disease

Plants were selected from each variety for recording observations on soybean mosaic virus incidence. Percent disease incidence for each test variety was recorded at 90 DAS (Nagaraj, 2013) and calculated by using formula where ratio of number of plants infected by SMV to the total number of plants in each rows of test genotype is taken and expressed in percent. The percent disease index (PDI) was recorded using a 0-5 point disease rating scale, which had six categories given by Bachkar *et al*., (2019).

Rating	Grades	Description
0	Highly resistant (HR)	0 (No Symptoms)
1	Resistant (R)	0.1-20 % leaves exhibiting symptoms
2	Moderately Resistant (R)	20.1-40 % leaves exhibiting symptoms
3	Moderately susceptible	40.1-60 % leaves exhibiting symptoms
4	Susceptible (S)	60.1-80 % leaves exhibiting symptoms
5	Highly susceptible (HS)	80.1-100 % leaves exhibiting symptoms

3.16 Harvest and post-harvest operations of soybean

The crop harvest was completed at 100 DAS. The crop was harvested plot wise after about 80% of the pods became mature. The harvested pods were sorted into individual bags for each plot separated by healthy and infected. They were taken to the threshing floor and sun dried for three days. Afterwards the seeds were separately weighed.

3.17 Yield reduction

Percent yield reduction in terms of grain weight was calculated as follows (Mousanejad *et al*., 2010).

$$\text{Yield reduction} = \frac{\text{Yield of healthy plant} - \text{Yield of infected plants}}{\text{Yield of healthy plant}} \times 100$$

3.18 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistis-10 and the mean differences were adjusted by Least Significance Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984). Tables bar diagram and photographs were used to present data as and when required. Correlation and regression were performed to find out the relationship between different parameters.

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted to evaluate the varietal performance of soybean varieties against major diseases of soybean in field condition and to determine the disease incidence (%) and percent disease index of major diseases of soybean. This chapter contains the explanation and description of the results obtained from the experiment. The results have been presented and possible interpretations have been given under the following headings:

4.1.1 Reaction of disease incidence (%) and percent disease index among soybean varieties for rust of soybean

Significant differences were found in average disease incidence (%) and percent disease index of different soybean varieties against rust of soybean disease during experimental period. The disease incidence (%) and percent disease index of different soybean varieties are presented in Table 1.

Disease incidence (%)

Significant variations were found in disease incidence of different soybean varieties against rust disease which ranges from 40% to 63.33%. The highest incidence was recorded in BINA soybean-1 (63.33%). On the other hand, the lowest incidence was recorded in BARI Soybean-5 (40%) which was statistically similar with other three varieties.

Percent disease index (PDI)

Significant variations were found in PDI which ranges from ranges from 35.8% to 57.48%. On the basis of percent disease index scale rating for rust of soybean, the highest PDI observed in BINA soybean-1 (57.48%) and given reaction was Highly Susceptible (HS). On the other hand, the lowest PDI was found in Shohag (35.8%) and given reaction was Susceptible (S).

Table 1: Reaction of disease incidence (%) and percent disease index among soybean varieties for rust of soybean

Varieties	Disease incidence (%)	Disease index and reaction	
		PDI	Reaction
BARI Soybean-5	40.00 b	41.49 b	S
BINA Soybean-3	46.66 b	46.16 b	S
Shohag	43.33 b	35.80 c	S
BINA Soybean-1	63.33 a	57.48 a	HS
Local(OP)	44.00 b	40.62 b	S
$LSD_{(0.05)}$	15.02	16.24	-
CV (%)	16.81	18.31	-

CV=Coefficient of variation, LSD= Least significant difference S= Susceptible HS= Highly Susceptible.

*LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.1.2 Effect of Soybean rust disease on growth and growth contributing characters of soybean

There were found significant differences in growth and growth contributing characters among different soybean varieties. Growth contributing characters such as plant height (cm), number of branches and number of leaves showed significant differences in response to rust of soybean. Effect of soybean rust disease on growth and growth contributing characters in response to rust of soybean are shown in Table 2.

Plant height (cm)

Plant height in response to rust of soybean showed significant difference among the varieties. The range of plant height varied from 42.55 to 63.44 (cm). Maximum height recorded in BINA Soybean-3 (63.44 cm) whereas minimum height was recorded in BINA Soybean-1 (42.55 cm), statistically indifferent with BARI Soybean-5 and Local (OP).

Number of branches

Number of branches in response of rust of soybean showed significant difference among the varieties. The average range of number of branches varied from 3.32 to 4.44. Maximum number of branches was recorded in BARI Soybean-5 (4.44) and minimum number of branches was recorded in Shohag (3.32).

Number of leaves

Number of leaves in response to rust of soybean showed significant difference among the varieties. The average range of number of leaves varied from 12.0 to 14.22. Maximum number of leaves was recorded in BARI Soybean-5 (14.22) which was statistically similar with BINA Soybean-3, Shohag, Local (OP) and minimum number of leaves was recorded in Local (OP) (12.0) followed by BINA Soybean-1 (12.66).

Table 2: Effect of Soybean rust disease on growth and growth contributing characters of soybean

Variety	Plant height (cm)	Number of branches	Number of leaves
BARI Soybean-5	48.77 b	4.44 a	14.22 a
BINA Soybean-3	63.44 a	3.55 ab	13.44 a
Shohag	50.88 b	3.32 b	13.10 a
BINA Soybean-1	42.55 b	3.66 ab	12.0 b
Local(OP)	43.00 b	3.66 ab	12.66 a
$LSD_{(0.05)}$	10.39	0.95	2.96
CV (%)	11.10	13.60	12.04

CV=Coefficient of variation, LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.1.3 Effect of rust disease on yield and yield contributing characters of soybean

Yield contributing characters such as number of pods/plant, number of Seed /pod, 100 seed weight (g), yield/plot (kg) and yield (t/ha) showed significant differences in response to rust of soybean. Effect of soybean rust disease on growth and growth contributing characters in response to rust of soybean are shown in Table 3.

Number of pods/plant

Number of pods/plant in response to rust of soybean showed significant difference among the varieties. The average range of number of pods/plant varied from 27.22 to 35.22. Maximum number of pods/plant was recorded in BARI Soybean-5 (35.22) and minimum number of pods/plant was recorded in Local (OP) (27.22), statistically similar with other varieties.

Number of seed /pod

Number of seeds/pod in response to rust of soybean showed significant difference among the varieties. The average range of number of pods/plant varied from 1.73 to 2.76. Maximum number of pods/plant was recorded in BARI Soybean-5 (2.76) and minimum number of pods/plant was recorded in BINA Soybean-1 (1.73).

100 seed weight (g)

In response to rust of soybean 100 seed weight (g) showed significant difference among the varieties. The average range of 100 seed weight varied from 10.44 to 12.77 (g). Maximum seed weight was recorded in BARI Soybean-5 (12.77 g) and minimum seed weight was recorded in Local (OP) (10.44 g) which was same as BINA Soybean-1 (10.44 g).

Yield/plot (kg)

In response to rust of soybean yield/plot was showed significant difference among the varieties. Range of yield/plot varied from 0.50 to 1.08 (Kg). Maximum yield/plot was recorded in BARI Soybean-5 (1.08 kg) statistically similar to BINA Soybean-3 (1.07 kg) and minimum yield/plot was recorded in Local (OP) (0.50 kg).

Yield (t/ha)

Yield (t/ha) of soybean varieties showed significant variation due to rust infection. The yield (t/ha) among the varieties ranges from 0.85 (t/ha) to 1.80 (t/ha). BARI Soybean-5 (1.80 t/ha) was statistically similar to BINA Soybean-3 (1.79 t/ha), whereas the lowest yield potential showed by Local (OP) (0.85 t/ha)

Table 3: Effect of rust disease on yield and yield contributing characters of soybean

Variety	Number of pods/plant	Number of seeds /pod	100 seed weight (g)	Yield/plot(kg)	Yield (t/ha)
BARI Soybean-5	35.22 a	2.76 a	12.77 a	1.08 a	1.80 a
BINA Soybean-3	31.33 ab	2.30 ab	13.44 a	1.07 a	1.79 a
Shohag	32.22 ab	2.20 bc	12.44 ab	0.76 ab	1.28 bc
BINA Soybean-1	28.99 ab	1.73 c	10.44 b	0.85 ab	1.43 ab
Local(OP)	27.22 ab	1.96 bc	10.44 b	0.50 b	0.85 c
$LSD_{(0.05)}$	6.67	0.50	2.18	0.47	0.36
CV (%)	11.43	12.30	9.73	19.13	18.45

CV=Coefficient of variation, LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.1.4 Healthy plant yield (t/ha) and Yield reduction due to rust disease among soybean varieties

Average healthy plant yield of the varieties BARI Soybean-5, Shohag, BINA Soybean-1, BINA Soybean-3 and Local (OP) were 2.05 t/ha, 1.55 t/ha, 2.86 t/ha, 1.93 t/ha and 0.98 t/ha respectively and infected plant yield (Table 3). It was seen that the highest yield reduction calculated for BINA Soybean-1 (50%) and lowest yield reduction recorded in BINA Soybean-3 (7.25%). The % yield reduction of the soybean varieties due to rust disease infection are presented in Figure 1.

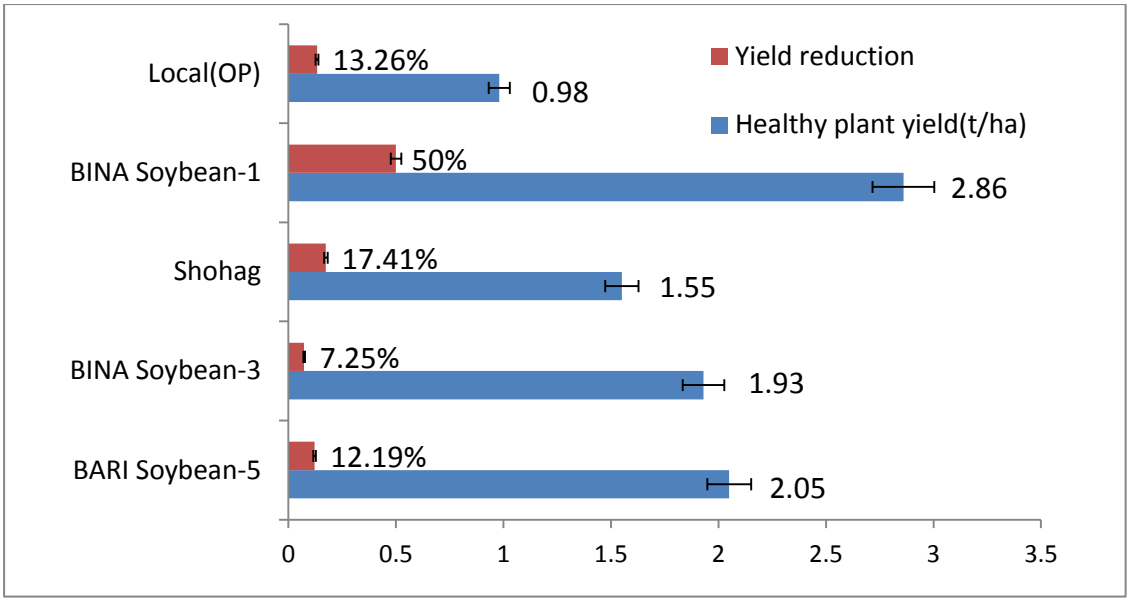


Figure 1: Healthy plant yield (t/ha) and Yield reduction due to rust disease among soybean varieties.

4.2.1 Reaction of disease incidence (%) and percent disease index among soybean varieties for powdery mildew of soybean

Significant differences were found in disease incidence (%) and percent disease index among soybean varieties against powdery mildew of soybean disease during experimental period. The disease incidence (%) and percent disease index of different soybean varieties are presented in Table 4.

Disease incidence (%)

Significant variations were found in disease incidence among soybean varieties against powdery mildew of soybean disease which ranges from 56.66%to 83.83%. The highest disease incidence was recorded in BARI soybean -5 (83.83%). On the other hand, the lowest incidence was recorded in Local (OP) (56.66%) which was statistically similar with BINA Soybean-3.

Percent disease index

There were significant variations found in percent disease index of powdery mildew among soybean varieties which ranges from 41.97% to 51.60%. On the basis of percent disease scale rating for rust of soybean the highest average PDI observed in BARI Soybean -5 (51.60%) given reaction was Highly Susceptible (HS), statistically same result found in Shohag (49.24%) and BINA Soybean-1

(48.145%) but showing reaction as Susceptible (S). On the other hand, the lowest PDI was found in BINA Soybean-3 (41.97%) given reaction was Susceptible (S).

Table 4: Reaction of disease incidence (%) and percent disease index among soybean varieties for powdery mildew of soybean.

Varieties	Disease incidence (%)	Disease index and reaction	
		PDI	Reaction
BARI Soybean-5	83.83 a	51.60 a	HS
BINA Soybean-3	60.00 b	41.97 b	S
Shohag	70.00 ab	49.24 ab	S
BINA Soybean-1	70.00 ab	48.14 ab	S
Local(OP)	56.66 b	44.03 b	S
$LSD_{(0.05)}$	19.44	7.58	-
CV (%)	15.19	10.57	-

CV=Coefficient of variation, LSD= Least significant difference, S=Susceptible, HS= Highly Susceptible

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.2.2 Effect of powdery mildew disease on growth and growth contributing characters of soybean

In case powdery mildew of soybean disease there were found significant differences in growth and growth contributing characters reduction of different soybean varieties. Growth contributing characters such as plant height (cm), number of branches and number of leaves showed significant differences in response to powdery mildew of soybean. Changes of growth and growth contributing characters in response to powdery mildew of soybean are shown in Table 5.

Plant height (cm)

Plant height in response to powdery mildew of soybean showed significant difference among the varieties. The average range of plant height varied from 42.88 to 58.66 (cm). Maximum plant height was recorded in BINA Soybean-3 (58.66 cm) and minimum plant height was recorded (42.88 cm).in Local (OP)

Number of branches

Number of branches in response to powdery mildew of soybean showed significant difference among the varieties. The average range of number of branches varied from 3.55 to 4.21. Maximum number of branches was recorded in BINA Soybean-3 (4.21) and minimum number of branches was recorded in Local (OP) (3.55) preceded by BARI Soybean-5. (3.59).

Number of leaves

Number of leaves in response to powdery mildew of soybean showed significant difference among the varieties. The average range of number of leaves varied from 11.22 to 14.22. Maximum number of leaves was recorded in BINA Soybean-3 (14.22) and minimum number of leaves was recorded in BARI Soybean-5 (11.22) which is statistically similar to Local (OP) (11.77).

Table 5: Effect of powdery mildew disease on growth and growth contributing character of soybean

Variety	Plant height (cm)	Number of branches	Number of leaves
BARI Soybean-5	50.55 b	3.59 b	11.22 b
BINA Soybean-3	58.66 a	4.21 a	14.22 a
Shohag	46.55 bc	3.66 b	12.55 a
BINA Soybean-1	44.77 bc	3.66 b	12.77 a
Local(OP)	42.88 c	3.55 b	11.77 b
$LSD_{(0.05)}$	6.53	0.96	3.87
CV (%)	7.13	13.68	16.06

CV=Coefficient of variation LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.2.3 Effect of powdery mildew disease on yield and yield contributing characters of soybean

Yield and yield contributing characters of soybean varieties were significantly varied due to powdery mildew infection. Yield contributing characters such as Number of pods/plant, Number of Seed /pod, 100 seed weight (g), Yield/plot, showed significant differences in response to powdery mildew of soybean. The effect on yield and yield contributing characters because of powdery mildew of soybean are shown in Table 6

Number of pods/plant

Number of pods/plant in response to powdery mildew of soybean showed significant difference among the varieties. The average range of pod number varied from 32.22 to 38.88. Maximum pod number was recorded in BINA Soybean-3 (38.88) and minimum pod number was recorded in BARI Soybean-5 (32.22).

Number of seed /pod

There were no significant variations among the varieties in number of seed/pod. The range of number of seeds varied from 1.83 to 2.43. Maximum number of seeds per pod was recorded in BINA Soybean-3 (2.66) and minimum number of seeds per pod was recorded in BARI Soybean-5 (1.83).

100 seed weight (g)

Significant variations found in 100 seed weight (g) in response to powdery mildew among the varieties of soybean. The range of 100 seed weight (g) varied from 13.44 to 12.33. Maximum 100 seed weight (g) was recorded in Shohag (13.44 g) and minimum 100 seed weight (g) was recorded in Local (OP) (12.33 g) preceded by BARI Soybean-5 (12.44 g).

Yield/plot (kg)

Yield/plot in response to powdery mildew of soybean showed significant difference among the varieties. The average range of reduction varied from 0.47 to 1.42 (kg). Maximum yield/plot was recorded in BINA Soybean-1 (1.42 kg) statistically similar to BINA Soybean-3 (1.02 kg) and minimum yield/plot was recorded in Local (OP) (0.47 kg).

Yield (t/ha)

Yield (ton/ha) of soybean varieties showed significant variation due to powdery mildew. The yield (t/ha) among the varieties ranges from 0.80 (t/ha) to 2.38 (ton/ha). The highest yield recorded in BINA Soybean-1 (2.38 t/ha). Whereas the lowest yield potential showed by Local (OP) (0.80t/ha) preceded by BARI Soybean-5 (1.24 t/ha).

Table 6: Effect of powdery mildew disease on yield and yield contributing characters of soybean

Variety	Number of pods/plant	Number of seed /pod	100 seed weight (g)	Yield/plot (kg)	Yield (t/ha)
BARI Soybean-5	32.22 b	2.43 a	12.44 ab	0.74 b	1.24 bc
BINA Soybean-3	38.88 a	1.83 b	13.77 a	1.02 ab	1.72 ab
Shohag	35.33 ab	2.16 ab	13.44 ab	0.80 b	1.35 bc
BINA Soybean-1	35.33 ab	2.05 ab	12.77 ab	1.42 a	2.38 a
Local(OP)	34.55 ab	2.17 ab	12.33 b	0.47 c	0.80 c
$LSD_{(0.05)}$	6.61	0.56	1.42	0.84	1.38
CV (%)	9.96	14.18	5.85	13.81	16.20

CV=Coefficient of variation, LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.2.4 Healthy plant yield (t/ha) and Yield reduction due to powdery mildew disease among soybean varieties

Average healthy plant yield of the varieties BARI Soybean-5, Shohag, BINA Soybean-1, BINA Soybean-3 and Local (OP) were 1.95 t/ha, 1.47 t/ha, 2.76 t/ha, 2.15 t/ha and .96 t/ha respectively and infected plant yield (Table 6). It was seen that the highest yield reduction calculated for BARI Soybean-5 (36.41%) and the lowest yield reduction recorded in Shohag (8.16%) followed by BINA Soybean-1 (13.76%). The yield reduction % of different soybean varieties due to powdery mildew infection is presented in Figure 2.

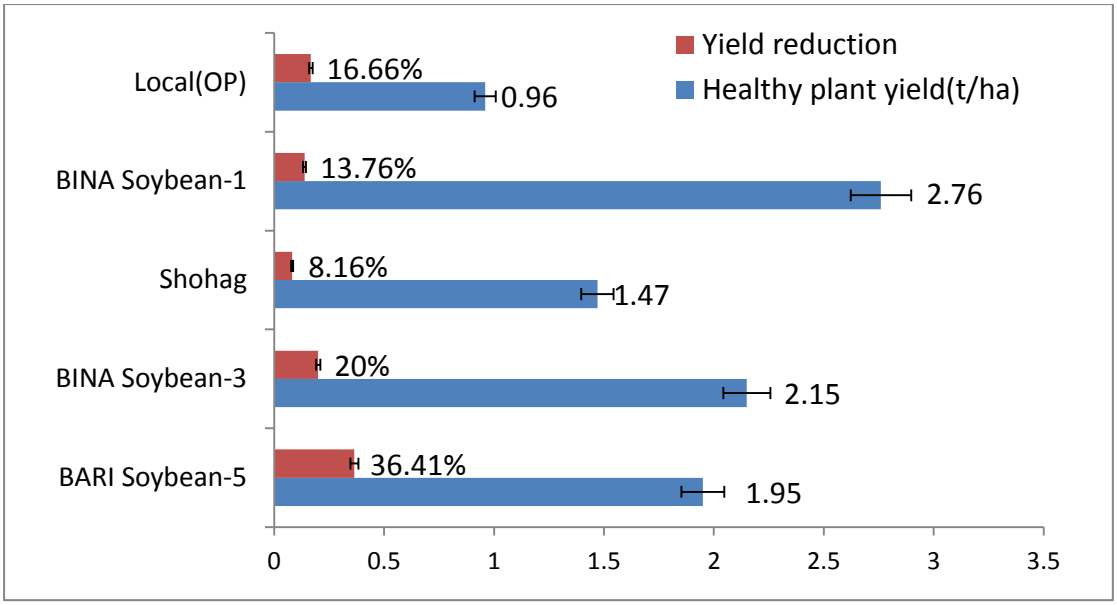


Figure 2: Healthy plant yield (t/ha) and Yield reduction due to powdery mildew disease among soybean varieties.

4.3.1 Reaction of disease incidence (%) and percent disease index among soybean varieties for anthracnose of soybean

Significant differences were found in disease incidence (%) and percent disease index of different soybean varieties against anthracnose of soybean disease during experimental period. The disease incidence (%) and percent disease index of different soybean varieties are presented in Table 7

Disease incidence (%)

Significant variations were found in disease incidence (%) of different soybean varieties against anthracnose of soybean disease which ranges from 35.33% to 54.66%. The highest incidence was recorded in Local (OP) (54.66%). One the other hand lowest incidence was recorded in BINA soybean-1 (35.33%).

Percent disease index (PDI)

There were significant variations found in PDI among the different soybean varieties for anthracnose of soybean which ranges from 24.71% to 47.49%. On the basis of percent disease index scale rating for anthracnose of soybean the highest PDI observed in Local (OP) (47.49%) given reaction was Susceptible

(S). On the other hand, the lowest PDI was found in BARI soybean -5 (24.71%) given reaction was Moderately Susceptible (MS).

Table 7: Reaction of disease incidence (%) and percent disease index among soybean varieties for anthracnose of soybean

Varieties	Disease incidence (%)	Disease index and reaction	
		PDI	Reaction
BARI Soybean-5	40.00 b	24.71 c	MS
BINA Soybean-3	40.00 b	41.66 a	S
Shohag	43.33 b	40.27 a	S
BINA Soybean-1	35.33 c	33.33 b	S
Local(OP)	54.66 a	47.49 a	S
$LSD_{(0.05)}$	8.82	13.76	-
CV (%)	10.75	14.87	-

CV=Coefficient of variation, LSD= Least significant difference, MS = Moderately Susceptible, S= Susceptible

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different

4.3.2 Effect of anthracnose disease on growth and growth contributing characters of soybean

In case anthracnose of soybean disease there were found significant differences in growth and growth contributing characters among different soybean varieties. Growth contributing characters such as plant height (cm), number of branches, number of leaves which showed significant differences in response to anthracnose of soybean. The effect on growth and growth contributing characters in response to anthracnose of soybean are shown in Table 8

Plant height (cm)

Plant height in response to anthracnose of soybean showed significant difference among the varieties. The range of plant height varied from 42.99 to

57.99 (cm). Maximum plant height was recorded in BARI Soybean-5 (57.99 cm) and minimum plant height was recorded in Local (OP) (42.99 cm).

Number of branches

Number of branches in response to anthracnose of soybean showed significant difference among the varieties. The range of number of branches varied from 2.66 to 4.33. Maximum number of branches was recorded in BARI Soybean-5 (4.33) and minimum number of branches was recorded in Local (OP) (2.66).

Number of leaves

Number of leaves in response to anthracnose of soybean showed significant difference among the varieties. The range of number of leaves varied from 11.22 to 14.11. Maximum number of leaves was recorded in BARI Soybean-5 (14.11) and minimum number of leaves was recorded in Local (OP) (11.22).

Table 8: Effect of anthracnose disease on growth and growth contributing characters of soybean

Variety	Plant height (cm)	Number of branches	Number of leaves
BARI Soybean-5	57.99 a	4.33 a	14.11 a
BINA Soybean-3	47.88 b	3.92 ab	11.99 b
Shohag	46.22 b	3.88 ab	12.44 a
BINA Soybean-1	45.22 b	3.99 ab	13.11 a
Local(OP)	42.99 b	2.66 b	11.22 b
$LSD_{(0.05)}$	9.65	0.53	3.80
CV (%)	10.50	9.58	16.08

CV=Coefficient of variation, LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.3.3 Effect of anthracnose disease on yield and yield contributing characters of soybean

Yield and yield contributing characters of soybean varieties were varied significantly due to anthracnose infection. Yield contributing characters such as Number of pods/plant, Number of Seed /pod, 100 seed weight (g), Yield/plot (kg). Reduction of these characters showed significant differences in response to anthracnose of soybean. The effect on growth and growth contributing characters in response to anthracnose of soybean are shown in Table 9.

Number of pods/plant

Number of pods/plant in response to anthracnose of soybean showed significant difference among the varieties. The range of pod number varied from 29.22 to 38.55. Maximum pod numbers was recorded in BARI Soybean-5 (38.55) and minimum pod number was recorded in Local (OP) (29.22).

Number of seed /pod

Number of seeds/pod in response to anthracnose of soybean showed significant difference among the varieties. The average range of number of seeds varied from 1.96 to 2.66. Maximum number of seeds per pod was recorded in BARI Soybean-5 (2.66) and minimum number of seeds per pod was recorded in Local (OP) (1.96).

100 seed weight (g)

100 seed weight in response to anthracnose of soybean showed significant difference among the varieties. The average range of hundred seed weight varied from 12.44 to 13.77. Maximum hundred seed weight was recorded in BINA Soybean-3 (13.77) followed by BARI Soybean-5 and minimum hundred seed weight was recorded in Local (OP) (12.44)

Yield/plot (kg)

Yield/plot in response to anthracnose of soybean showed significant difference among the varieties. The average range of effect varied from 0.38 to 1.36 (kg). Maximum yield/plot was recorded in BINA Soybean-1 (1.36 kg) followed by BARI Soybean-5 (1.08 kg) and minimum yield/plot was recorded in Local (OP) (0.58 kg).

Yield (t/ha)

Yield (t/ha) of soybean varieties showed significant variation due to anthracnose. The yield (t/ha) among the varieties ranges from 0.65 (t/ha) to 2.28 (t/ha). The highest yield recorded in BINA Soybean-1 (2.28 t/ha) followed by BARI Soybean-5 (1.82 t/ha). Whereas the lowest yield potential showed by Local (OP) (0.65 t/ha).

Table 9: Effect of anthracnose disease on yield and yield contributing characters of soybean

Variety	Number of pods/plant	Number of seed /pod	100 seed weight (g)	Yield/plot (kg)	Yield (t/ha)
BARI Soybean-5	38.55 a	2.66 a	13.44 ab	1.08 ab	1.82 b
BINA Soybean-3	34.77 ab	2.54 a	13.77 a	0.92 b	1.54 b
Shohag	34.77 ab	2.20 a	12.77 ab	0.68 b	1.15 bc
BINA Soybean-1	35.33 ab	2.11 a	12.77 ab	1.36 a	2.28 a
Local(OP)	29.22 b	1.96 b	12.44 b	0.38 c	0.65 c
$LSD_{(0.05)}$	8.76	0.74	1.18	0.34	0.44
CV (%)	13.38	17.24	4.81	19.45	18.38

CV=Coefficient of variation, LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different

4.3.4 Healthy plant yield (t/ha) and Yield reduction due to anthracnose disease among soybean varieties

Average healthy plant yield of the varieties BARI Soybean-5, Shohag, BINA Soybean-1, BINA Soybean-3 and Local (OP) were 1.91 t/ha, 1.35 t/ha, 2.75 t/ha, 1.73 t/ha and .81 t/ha respectively and infected plant yield (Table 9). It was seen that the highest yield reduction calculated for Local (OP) (19.75%) and the lowest yield reduction recorded in BARI Soybean-5 (4.71%). The yield reduction (%) of different soybean varieties due to anthracnose infection is presented in Figure 3.

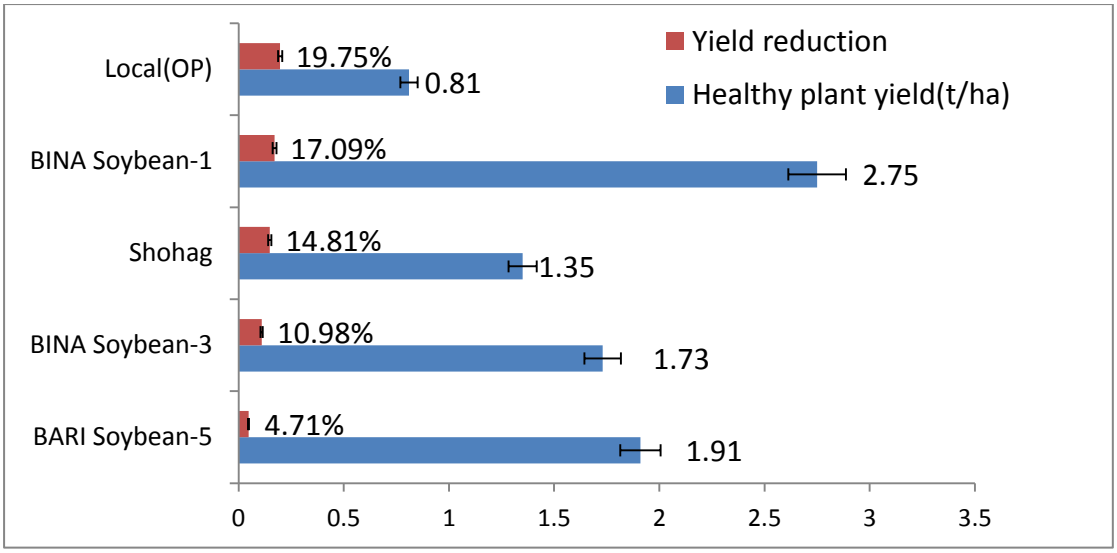


Figure 3: Healthy plant yield (t/ha) and Yield reduction due to anthracnose disease among soybean varieties.

4.4.1 Reaction of disease incidence (%) and percent disease index among soybean varieties for soybean mosaic disease

Significant differences were found in average disease incidence (%) and percent disease index of different soybean varieties against soybean mosaic disease during experimental period. The disease incidence (%) and Percent disease index of different soybean varieties are presented in Table 10

Disease incidence (%)

Significant variations were found in disease incidence (%) of different soybean varieties against soybean mosaic disease ranges from 20% to 40%. The highest incidence was recorded in Shohag and Local (OP) (40%). On the other hand, the lowest incidence was recorded in BINA Soybean-3 (20%).

Percent disease index

There were significant variations found in PDI among the different soybean varieties against soybean mosaic disease which ranges from 24.69% to 40.50%. One the basis of percent disease index scale rating for rust of soybean the highest average PDI observed in Local (OP) (40.50%) given reaction was Moderately Susceptible (MS). On the other hand, the lowest PDI was found in BINA soybean-3 (24.69%) given reaction was Moderately Resistant (MR).

Table 10: Reaction of disease incidence (%) and percent disease index among soybean varieties for soybean mosaic disease

Varieties	Disease incidence (%)	Disease index and reaction	
		PDI	Reaction
BARI Soybean-5	33.33 a	40.49 a	MS
BINA Soybean-3	20.00 b	24.69 b	MR
Shohag	40.00 a	40.10 a	MS
BINA Soybean-1	33.33 a	37.77 a	MS
Local(OP)	40.00 a	40.50 a	MS
$LSD_{(0.05)}$	13.14	14.56	-
CV (%)	19.95	17.80	-

CV=Coefficient of variation, LSD= Least significant difference, MR = Moderately Resistant, MS = Moderately Susceptible

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.4.2 Effect of soybean mosaic disease on growth and growth contributing characters of soybean

In case soybean mosaic disease there were found appreciable differences in growth and growth contributing characters of different soybean varieties. Growth contributing characters such as plant height, average number of branches, average number of leaves, showed significant differences in response to soybean mosaic disease. Effect on growth and growth contributing characters due to soybean mosaic disease are shown in Table 11.

Plant height (cm)

Plant height in response to soybean mosaic disease showed significant difference among the varieties. The average range of plant height varied from 38.77 to 60.66 (cm). Maximum plant height was recorded in BINA Soybean-3 (57.99 cm) and minimum plant height was recorded in Local (OP) (42.99 cm).

Number of branches

Number of branches in response to soybean mosaic disease showed significant difference among the varieties. The average range of number of branches varied from 3.55 to 4.32. Maximum number of branches was recorded in BINA Soybean-3 (4.32) minimum number of branches was recorded in BINA Soybean-1 (2.66).

Number of leaves

Number of leaves in response to soybean mosaic disease showed significant difference among the varieties. The average range of number of leaves varied from 11.33 to 14.33. Maximum number of leaves was recorded in BINA Soybean-3 (14.33) and minimum number of leaves was recorded in Local (OP) (11.33).

Table 11: Effect of soybean mosaic disease on growth and growth contributing characters of soybean

Variety	Plant height (cm)	Number of branches	Number of leaves
BARI Soybean-5	43.88 b	3.66 b	12.11 a
BINA Soybean-3	60.66 a	4.32 a	14.33 a
Shohag	40.95 b	3.88 b	12.66 a
BINA Soybean-1	41.22 b	3.55 b	13.11 a
Local(OP)	38.77 b	3.67 b	11.33 b
$LSD_{(0.05)}$	7.57	0.97	4.15
CV (%)	8.92	13.50	17.36

CV=Coefficient of variation, LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.4.3 Effect of Soybean mosaic disease on yield and yield contributing characters of soybean

Yield and yield contributing characters of soybean varieties were affected due to soybean mosaic disease infection. Yield contributing characters such as Number of pods/plant, Number of Seed /pod, 100 seed weight, Yield/plot, showed significant differences in response to soybean mosaic disease. The reduction of growth and growth contributing characters in response to soybean mosaic disease are shown in Table 12

Number of pods/plant

Number of pods/plant in response to soybean mosaic disease showed significant difference among the varieties. The average range of pod number varied from 28.99 to 38.66. Maximum pod number was recorded in BINA Soybean-3 (38.66) and minimum pod number was recorded in Local (OP) (28.99).

Number of seed /pod

Number of seeds/pod in response to soybean mosaic disease showed non significance difference among the varieties. The average range of number of seeds varied from 1.97 to 2.33. Maximum number of seeds per pod was recorded in BINA Soybean-3 (2.33) and minimum number of seeds per pod was recorded in BARI Soybean-5 (1.97).

100 seed weight (g)

100 seed weight in response to soybean mosaic disease showed significant difference among the varieties. The average range of hundred seed weight varied from 12.44 to 13.77. Maximum hundred seed weight was recorded in BINA Soybean-3 (13.44) and minimum hundred seed weight was recorded in Shohag (12.11).

Yield/plot (kg)

Yield/plot in response to soybean mosaic disease showed significant difference among the varieties. The average range of yield/lot varied from 0.44 to 1.49

(kg). Maximum yield/plot was recorded in BINA Soybean-1 (1.49 kg) preceded by BINA Soybean-3 (1.06 kg) and minimum yield/plot was recorded in Local (OP) (0.44 kg).

Yield (t/ha)

Yield (t/ha) of soybean varieties showed significant variation due to soybean mosaic disease. The yield (t/ha) among the varieties ranges from 0.75 (t/ha) to 2.5 (t/ha). The highest yield recorded in BINA Soybean-1 (2.50 t/ha) preceded by BINA Soybean-3 (1.78 t/ha). Whereas the lowest yield potential showed by Local (OP) (0.65 t/ha).

Table 12: Effect of Soybean mosaic disease on yield and yield contributing characters of soybean

Variety	Number of pods/plant	Number of seed /pod	100 seed weight (g)	Yield/plot (kg)	Yield (t/ha)
BARI Soybean-5	34.88 ab	1.97 a	12.44 ab	0.83 b	1.40 b
BINA Soybean-3	38.66 a	2.33 a	13.44 a	1.06 ab	1.78 ab
Shohag	35.66 ab	2.13 a	12.11 b	0.82 b	1.38 b
BINA Soybean-1	35.44 ab	1.97 a	13.44 a	1.49 a	2.50 a
Local(OP)	28.99 b	2.21 a	12.44 ab	0.44 c	0.75 c
$LSD_{(0.05)}$	9.14	0.69^{NS}	1.20	0.41	0.65
CV (%)	13.98	17.51	5.01	19.80	17.34

CV=Coefficient of variation, LSD= Least significant difference

* LSD was calculated at (.05) level of significant, means followed by same lettering is not significantly different.

4.4.4 Healthy plant yield (t/ha) and Yield reduction due to soybean mosaic disease among soybean varieties

Average healthy plant yield of the varieties BARI Soybean-5, Shohag, BINA Soybean-1, BINA Soybean-3 and Local (OP) were 1.63 t/ha, 1.65 t/ha, 2.77 t/ha, 1.92 t/ha and .88 t/ha respectively and infected plant yield (Table 12). It was seen that the highest yield reduction calculated for Shohag (16.36%). On the other hand, BINA Soybean-3 (7.29%) had the lowest yield reduction. The yield reduction (%) of different soybean varieties due to soybean mosaic disease is presented in Figure 4.

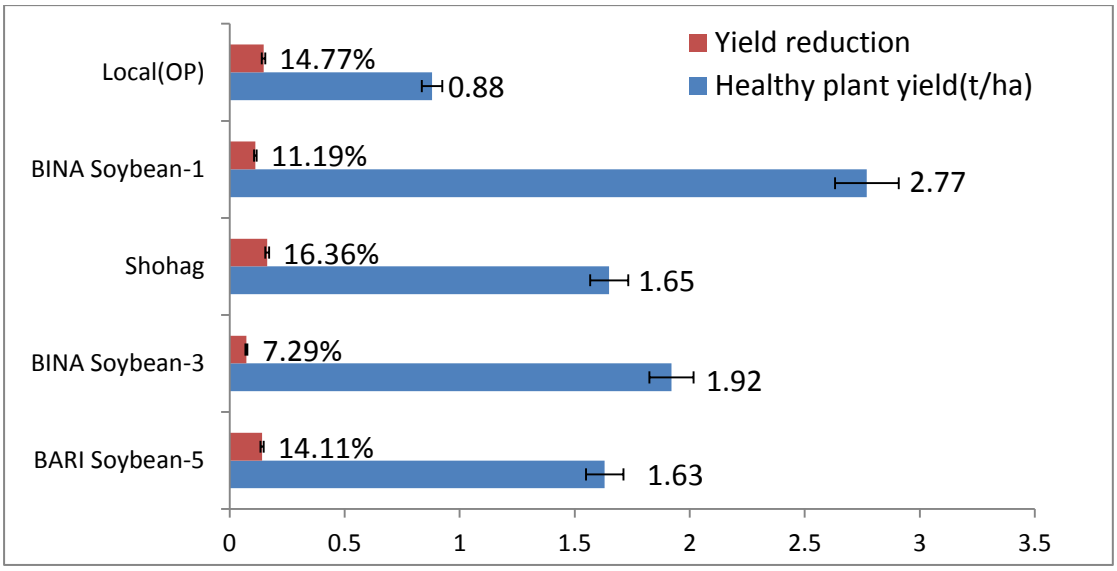


Figure 4: Healthy plant yield (t/ha) and Yield reduction due to soybean mosaic disease among soybean varieties

4.5 Comparison among disease incidence (%) of major diseases of different soybean varieties during field experiment

Comparison of individual soybean variety against disease incidence (%) of major diseases during field experiment is shown in Figure 5.

The Figure 5 presented that in case of BARI Soybean-5 the highest disease incidence (83.3%) in powdery mildew and the lowest disease incidence (33.33%) in soybean mosaic disease. In case of BINA Soybean-3 the highest disease incidence (60 %) in powdery mildew and the lowest disease incidence (20%) in soybean mosaic disease. For Shohag the highest disease incidence

(70%) in powdery mildew and the lowest disease incidence (40%) in soybean mosaic disease. For BINA Soybean-1 the highest disease incidence (70%) in powdery mildew and the lowest disease incidence (33.33%) in anthracnose disease. On the other hand, for Local (OP) the highest disease incidence (56.66%) in powdery mildew and the lowest disease incidence (40%) in soybean mosaic disease.

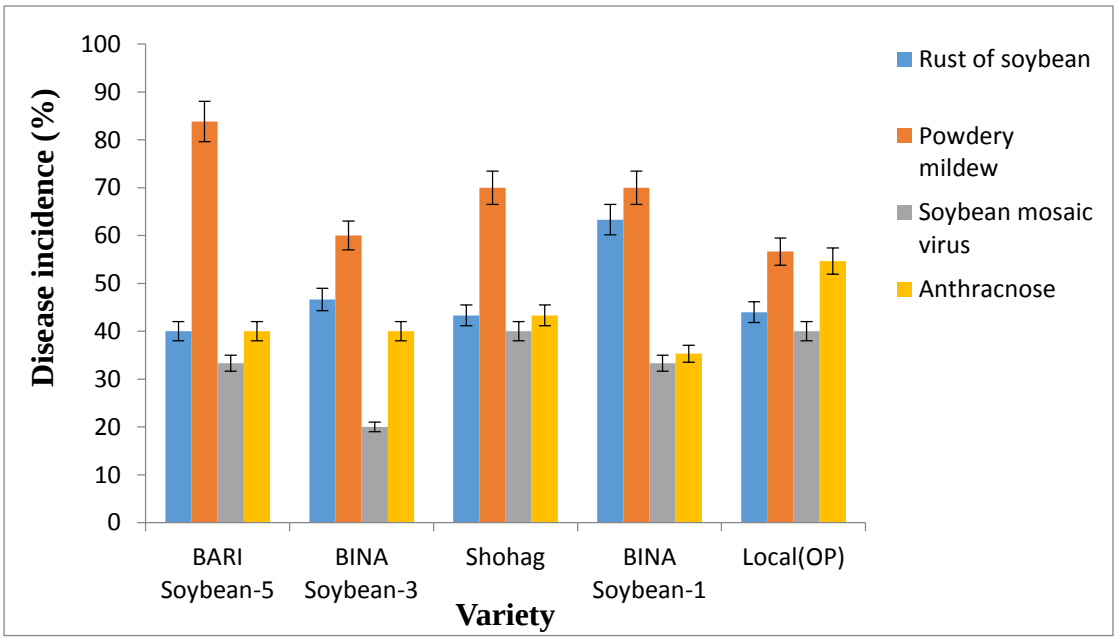


Figure 5: Comparison among disease incidence (%) of major diseases of different soybean varieties during field experiment

4.6 Comparison of different soybean varieties against percent disease index of major diseases during field experiment

Comparison of individual soybean variety against percent disease index of major diseases during field experiment is shown in Figure 6.

The Figure 6 presented that incase of BARI Soybean-5 the highest percent disease index (51.6 %) in powdery mildew and the lowest percent disease index (24.71%) in anthracnose. In case of BINA Soybean-3 the highest percent disease index (41.97 %) in powdery mildew and the lowest percent disease index (24.69%) in soybean mosaic virus disease. For Shohag (PB-1) the highest percent disease index (49.24%) in powdery mildew and the lowest percent disease index (35.8%) in rust disease. For BINA Soybean-1 the highest percent disease index (57.48%) in rust and the lowest percent disease index

(33.33%) in anthracnose disease. One the other hand, for Local (OP) the highest percent disease index (57.48%) in anthracnose and the lowest percent disease index (33.33%) in soybean mosaic virus disease.

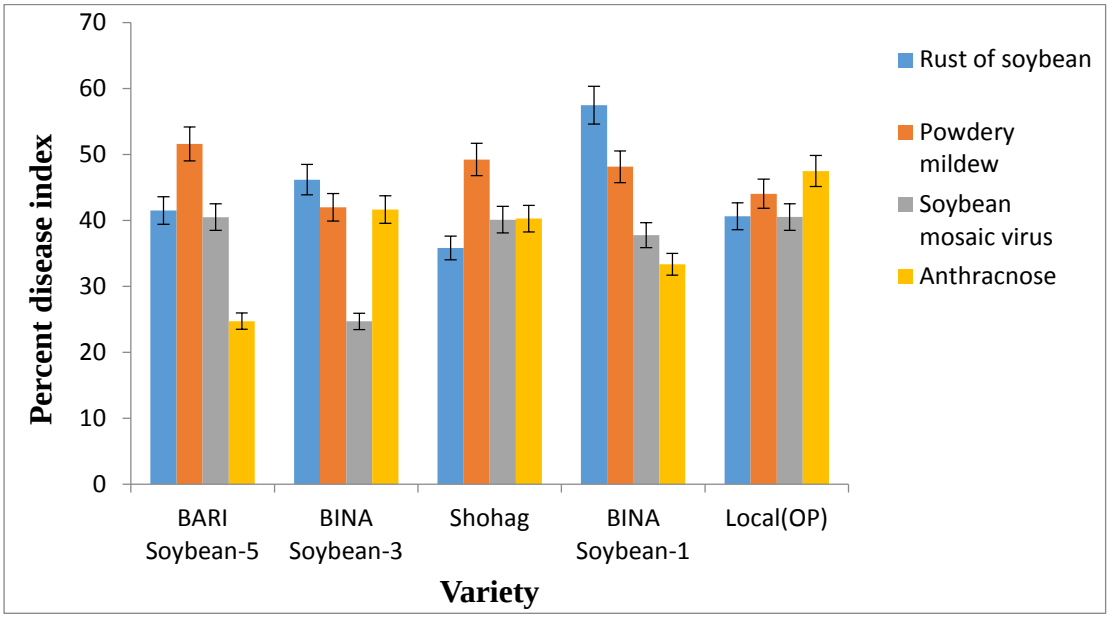


Figure 6: Comparison of different soybean varieties against percent disease index of major diseases during field experiment

4.7 Varietal performance of yield (t/ha) in relation to four major diseases infection in field

Significant differences were found effect on yield due to major diseases infection of individual variety. The yield of individual variety in reaction to disease infection of major diseases is shown in Figure 7

BARI Soybean-5 showed highest yield (1.82 t/ha) in anthracnose while lowest yield recorded (1.24 t/ha) in response to powdery mildew. BINA Soybean-3 showed the highest yield potential against soybean mosaic disease (1.79 t/ha) and lowest was recorded in anthracnose (1.64 t/ha). Shohag showed the highest yield (1.35 t/ha) in soybean mosaic disease while the lowest yield recorded (1.15 t/ha) in response to anthracnose. BINA Soybean-1 showed the highest yield potential against powdery mildew (2.56 t/ha) and the lowest was recorded in rust (1.43 t/ha). In case of Local (OP) the highest yield potential against soybean mosaic disease (0.85 t/ha) and the lowest was recorded in anthracnose (0.65 t/ha).

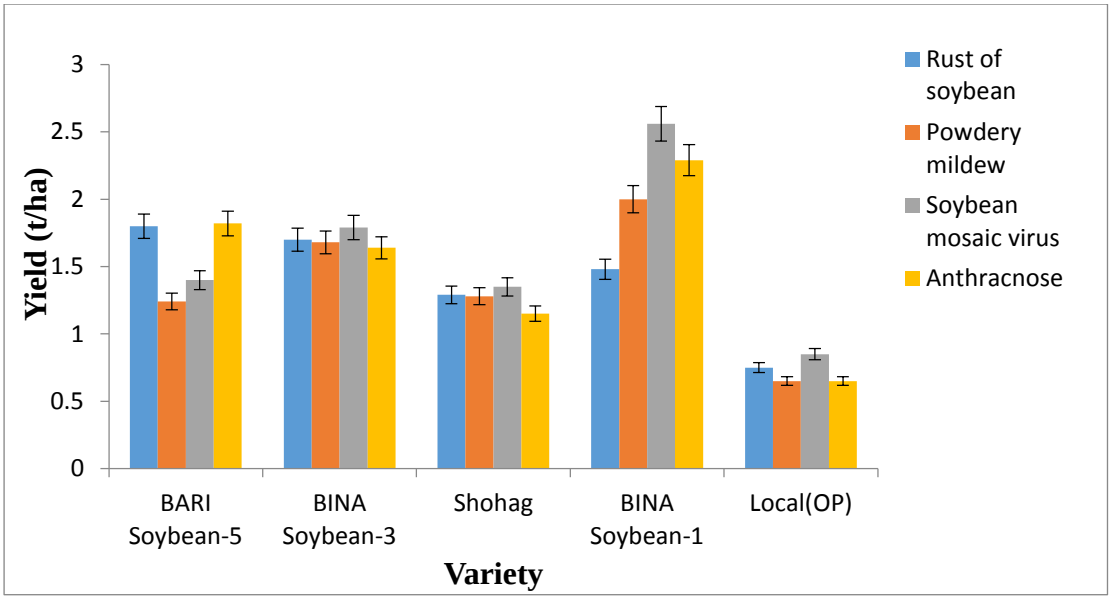
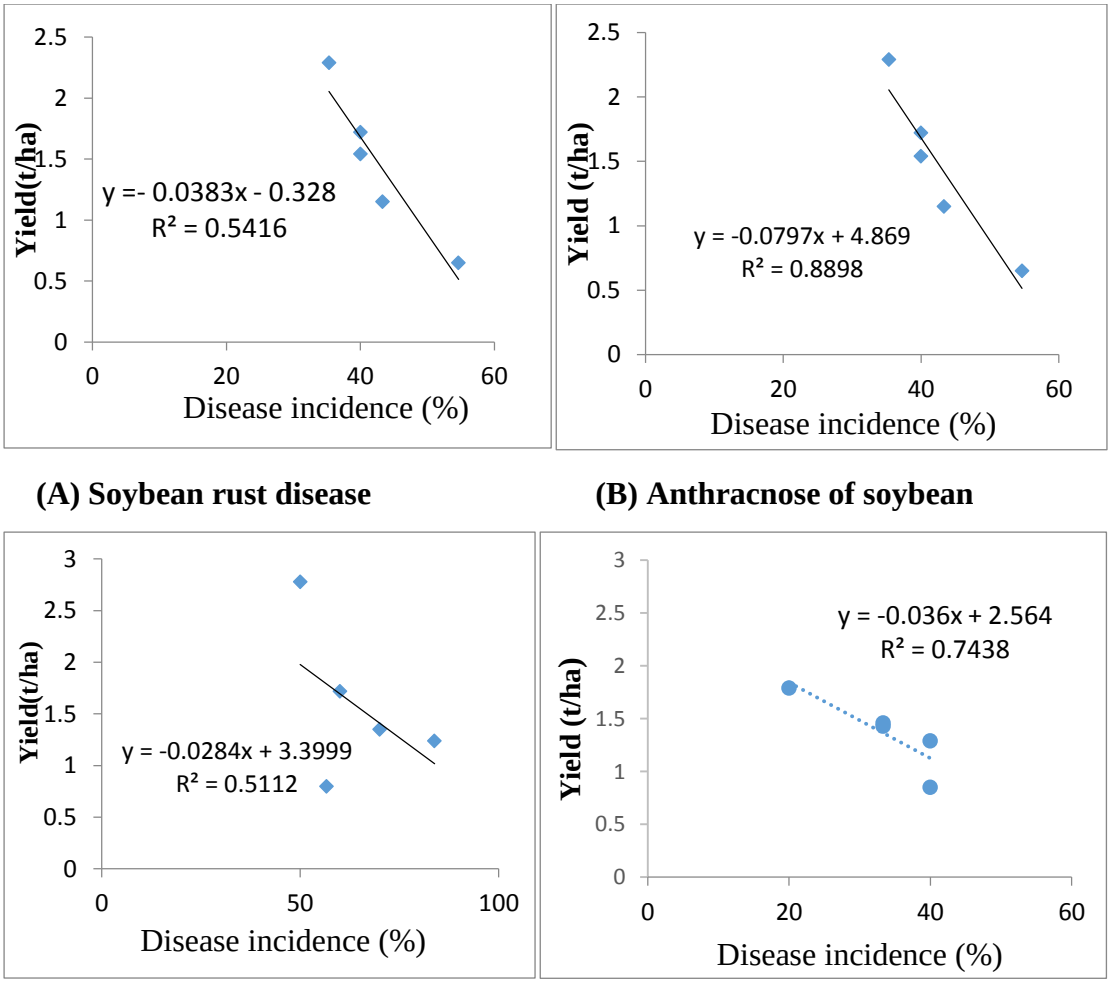


Figure 7: Varietal performance on yield in relation to disease infection of major diseases

4.8 Relationship between identified major disease incidence (%) and yield (t/ha) among different soybean varieties

There were negative relations found between disease incidence (%) of identified major diseases and yield (t/ha) of different soybean varieties are shown in figure 8. This figure showed that with the increase of disease incidence (%) among the soybean varieties in identified major disease, yield of soybean decreased. A regression line was fitted between disease incidence (%) of major soybean diseases and yield of soybean. In case of Soybean rust disease the contribution of regression (R^2=0.5416) indicated that 54.16% yield of soybean would be affected by Soybean rust disease. For Anthracnose of soybean the contribution of regression (R^2=0.8898) indicated that 88.98% yield of soybean would be affected by Anthracnose of soybean. One the other hand Powdery mildew of soybean the contribution of regression (R^2=0.5112) indicated that 51.12% yield of soybean would be affected by Powdery mildew of soybean. For *Soybean mosaic virus* the contribution of regression (R^2=0.7438) indicated that 74.38% yield of soybean would be affected by *Soybean mosaic virus*.



(A) Soybean rust disease **(B) Anthracnose of soybean**

(C) Powdery mildew of soybean **(D) *Soybean mosaic virus***

Figure 8: Relationship between identified major disease incidence (%) and yield (t/ha) among different soybean varieties.

DISCUSSION

Soybean is a leguminous plant known as Golden bean which belongs to *Fabaceae* family. It is a versatile and fascinating oil yielding crop with innumerable possibilities of not only improving agriculture but also supporting industries. Soybean provides cholesterol free oil (19.94%) and high quality protein (36.49%). It is a rich source of lysine 7.3% (USDA, 2003). Soybean besides having high yielding potential average worldwide yield was 2.8 ton per hectare (FAOSTAT, 2015). The global production of soybeans is 337 million tones (USDA, 2018). It can be cultivated in both the kharif and rabi seasons in Bangladesh soybean yield is 1.54 ton per hectare and total production is 97000 tones by cultivating almost 63000 hectare of land (BBS, 2017). Soybean plant health is a critical component of profitable soybean production. The average annual yield losses due to soybean diseases in the United States are approximately 11% (Hartman *et al*., 2015). Soybean is known to suffer from more than 100 pathogens among the diseases. Plant pathogenic fungi and virus are an important group of organisms that compromise soybean health. Among diseases of soybean rust of soybean caused by *Phakopsora pachyrhizi*, powdery mildew of soybean (*Microsphaera diffusa*), Anthracnose (*Colletotrichum truncatum*), *Soybean mosaic virus* are the major diseases (Singh and Shrivastava, 2007).

The aim of this study was to evaluate the varietal performance of soybean varieties against major diseases of soybean in field condition and to determine the disease incidence (%) and percent disease index of major diseases of soybean. The present piece of research work was placed in the central research field under Department of Plant Pathology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. Five widely cultivated varieties namely BARI Soybean-5, Shohag (PB-1), BINA Soybean-1, BINA Soybean-3, Local (OP) were used in the experiment.

During evaluation in field against major diseases, four major diseases were considered through visible symptoms. The result of this study revealed that BARI Soybean-5, Shohag, BINA Soybean-3 showed better performance against the major diseases in case of disease incidence (%), percent disease index (PDI).

Rust of soybean

Significant variations were found in disease incidence (%) and percent disease index of different soybean varieties against rust of soybean, the highest disease incidence was recorded in BINA soybean-1 (63.33%) and the lowest incidence was recorded in BARI Soybean-5 (40%). Similar investigation was conducted by Hartman *et al*. (1991), he found rust infection was ranged between 14 to 95 (%) on TK-5 and 0 to 34 (%) on SREB15-A The highest PDI observed in BINA soybean-1 (57.48%) given reaction was Moderately Susceptible (MS), the lowest PDI was found in Shohag (35.8%) given reaction was Susceptible (S).Similar investigation was conducted by Verma *et al.* (2004) they evaluated 242 genotypes among them one line (SJ-1) as highly resistant, three lines *viz*., JS-19, RPSP-728, PK-838 as resistant, 16 lines as moderately resistant and rest were either susceptible or highly susceptible, Ramteke *et al*. (2004); Hartman *et al*. (1992) conducted same investigation.

Maximum plant height was recorded in BINA Soybean-3 (63.44 cm) and minimum height was recorded in BINA Soybean-1 (42.55 cm) followed by Local (OP) (43.0 cm). Maximum number of branches was recorded in BARI Soybean-5 (4.44) and minimum number of branches was recorded in Shohag (3.32). Maximum number of leaves was recorded in BARI Soybean-5 (14.22) and minimum number of leaves was recorded in Local (OP) (12.0) followed by BINA Soybean-1 (12.66). Singh (1973), also denoted that growth parameters influenced by disease infection.

Maximum number of pods/plant was recorded in BARI Soybean-5 (35.22) and minimum number of pods/plant was recorded in Local (OP) (27.22) followed by BINA Soybean-1 (28.99). Maximum number of seeds/pod was recorded in BARI Soybean-5 (2.76) and minimum number of pods/plant was recorded in BINA Soybean-1 (1.73). Maximum 100 seed weight was recorded in BARI Soybean-5 (12.77 g) and minimum 100 seed weight was recorded in Local (OP) (10.44 g) followed by BINA Soybean-1 (10.44 g). The highest yield recorded in BARI Soybean-5 (1.08 kg) statistically similar to BINA Soybean-3 (1.07 kg) and minimum yield/plot was recorded in Local (OP) (0.50 kg).BARI Soybean-5 (1.80 t/ha) statistically similar to BINA Soybean-3 (1.79 t/ha). Whereas the lowest yield potential showed by Local (OP) (0.85 t/ha). Almost similar result found by Bromfield, (1984); Sinclair, (1989); Yeh (1983).showed yield may be reduced 20-50 (%) due to rust of soybean.

Powdery mildew of soybean

The highest disease incidence against powdery mildew was recorded in BARI soybean -5 (83.83%) and the lowest incidence was recorded in Local (OP) (56.66%). The highest PDI observed against powdery mildew in BARI soybean -5 (51.60%) given reaction was Highly Susceptible (HS) and the lowest PDI was found in BINA soybean-3 (41.97%) given reaction was Susceptible (S). Similar findings were also reported by Almeida, *et al*. (2008); Mahesha, (2006) supported the outcome.Gonçalves *et al*. (2002) studied in a greenhouse and pots on incidence and PDI on soybean varieties due to powdery mildew.

Maximum plant height was recorded in BINA Soybean-3 (58.66 cm) and minimum plant height was recorded in (42.88 cm). Maximum number of branches was recorded in BINA Soybean-3 (4.21) and minimum number of branches was recorded in Local (OP) (3.55) followed by BARI Soybean-5. (3.59). Maximum number of leaves was recorded in BINA Soybean-3 (14.22) and minimum number of leaves was recorded in BARI Soybean-5 (11.22). Tanaka *et al*. (1993) said Hampton genotype growth was worst affected by powdery mildew

Maximum pod number was recorded in BINA Soybean-3 (38.88) and the minimum pod number was recorded in BARI Soybean-5 (32.22). The maximum number of seeds per pod was recorded in BINA Soybean-3 (2.66) and the minimum number of seeds per pod was recorded in BARI Soybean-5 (1.83). The maximum hundred seed weight was recorded in Shohag (13.44) and the minimum hundred seed weight was recorded in Local (OP) (12.33) followed by BARI Soybean-5 (12.44). The maximum yield/plot was recorded in BINA Soybean-1 (1.42 kg) statistically similar to BINA Soybean-3 (1.02 kg) and the minimum yield/plot was recorded in Local (OP) (0.47 kg).The highest yield recorded in BINA Soybean-1 (2.38 t/ha). Whereas the lowest yield potential showed by Local (OP) (0.80ton/ha) preceded by BARI Soybean-5 (1.24 t/ha). Almeida, *et al*. (2008) stated that powdery mildew of soybean can cause losses of up to 25%.

Anthracnose of soybean

The highest disease incidence of anthracnose of soybean was recorded in Local (OP) (54.66%) and lowest incidence was recorded in BINA soybean-1 (35.33%). Kulkarni (2009) conducted a study on anthracnose of green gram noticed incidence range from 21.36 to 58.97 % and during 2007, the disease severity noticed in the range of 24.67 to 60.07 %. The highest percent disease index of anthracnose of soybean observed in Local (OP) (47.49%) given reaction was Susceptible (S) and the lowest PDI was found in BARI soybean -5 (24.71%) given reaction was Moderately Susceptible (MS). Khare and Chacko (1983) screened 26 soybean varieties disease index was ranged between 0 to 58.2 (%), Manandhar *et al*. (1985) evaluated 200 soybean cultivars Only two varieties (Tarheel and PI 95-860) were found resistant to this disease. Shirshikar (1995) screened 42 cultivars of soybean and found none of the cultivars as either immune or highly resistant to the anthracnose disease.

Maximum plant height was recorded in BARI Soybean-5 (57.99 cm) and minimum plant height was recorded in Local (OP) (42.99 cm). Maximum number of branches was recorded in BARI Soybean-5 (4.33) and minimum

number of branches was recorded in Local (OP) (2.66). Maximum number of leaves was recorded in BARI Soybean-5 (14.11) and minimum number of leaves was recorded in Local (OP) (11.22). Manandhar *et al*. (1988) found disease can happen at all growth stage and affect the growth characters due to anthracnose of soybean.

Maximum pod number was recorded in BARI Soybean-5 (38.55) and minimum pod number was recorded in Local (OP) (29.22). Maximum number of seeds per pod was recorded in BARI Soybean-5 (2.66) and minimum number of seeds per pod was recorded in Local (OP) (1.96). Maximum hundred seed weight was recorded in BINA Soybean-3 (13.77) followed by BARI Soybean-5 and minimum hundred seed weight was recorded in Local (OP) (12.44). Maximum yield/plot was recorded in BINA Soybean-1 (1.36 kg) followed by BARI Soybean-5 (1.08 kg) and minimum yield/plot was recorded in Local (OP) (0.58 kg). The highest yield recorded in BINA Soybean-1 (2.28 t/ha) followed by BARI Soybean-5 (1.82 ton/ha). Whereas the lowest yield potential showed by Local (OP) (0.65 t/ha). Lenné and Sonoda (1982) stated that in *S. hamate*, 25 to 58 % yield was affected by anthracnose infection in soybean.

Soybean mosaic disease

The highest disease incidence against soybean mosaic disease was recorded in Shohag and Local (OP) (40%) and the lowest incidence was recorded in BINA Soybean-3 (20%). The highest average PDI observed in Local (OP) (40.50%) given reaction was Moderately Susceptible (MS) and the lowest PDI was found in BINA soybean-3 (24.69%) given reaction was Moderately Resistant (MR). Akhtar, *et al*. (1992) screened twelve varieties he got four varieties (Crow ford, Cico, Zane and 80-B- 4007) resistant to the virus, Shrirao, *et al*. (2009) evaluated 16 genotypes and reported that 14 entries were found absolutely resistant and two showed highly resistant reaction,

Maximum plant height was recorded in BINA Soybean-3 (57.99 cm) and minimum plant height was recorded in Local (OP) (42.99 cm). Maximum

number of branches was recorded in BINA Soybean-3 (4.32) and minimum number of branches was recorded in BINA Soybean-1 (2.66). Maximum number of leaves was recorded in BINA Soybean-3 (14.33) and minimum number of leaves was recorded in Local (OP) (11.33). Study on growth and growth contributing characters on hilly area done by Shaheenuzzamn *et al*., (2014) showed reduction of growth characters in soybean varieties due to soybean mosaic disease.

Maximum pod number was recorded in BINA Soybean-3 (38.66) and minimum pod number was recorded in Local (OP) (28.99). Maximum number of seeds/pod was recorded in BINA Soybean-3 (2.33) and minimum number of seeds/pod was recorded in BARI Soybean-5 (1.97). Maximum 100 seed weight was recorded in BINA Soybean-3 (13.44) and minimum 100 seed weight was recorded in Shohag (12.11). Maximum yield/plot was recorded in BINA Soybean-1 (1.49 kg) proceeded by BINA Soybean-3 (1.06 kg) and the minimum yield/plot was recorded in Local (OP) (0.44 kg).The highest yield recorded in BINA Soybean-1 (2.50 t/ha) preceded by BINA Soybean-3 (1.78 ton/ha). Whereas the lowest yield potential showed by Local (OP) (0.65 ton/ha). Seo *et al*., (2009), Cho and Goodman (1979), Steinlage *et al*. (2002), Hobbs et al. (2003) and Gunduz *et al*. (2004) said that in particular, infected soybean by SMV, plants may result in yield losses because of the noticeable reduction in the number of seeds produced by *Soybean mosaic virus* infected plants.

Yield reduction

The yield reduction of the soybean varieties from recommended yield due to rust the highest yield reduction calculated for BARI Soybean-5 (51.33%) and the lowest yield reduction recorded in BINA Soybean-3 (25.41%). Almost similar result found by Bromfield, (1984); Sinclair, (1989); Yeh (1983).showed yield may be reduced 20-50 (%) for rust of soybean. Due to powdery mildew infection the highest yield reduction calculated for BARI Soybean-5 (43.63%) and the lowest yield reduction recorded in BINA Soybean-1 (17.33%).

Almeida, *et al*. (2008) stated that powdery mildew of soybean can cause losses of up to 25%. Due to anthracnose infection the highest yield reduction calculated for Local (OP) (45.83%) and the lowest yield reduction recorded in BARI Soybean-5 (17.27%) almost similar like Backman *et al*., (1985); Sinclair, (1989); Lenné, J. M., and Sonoda, R. M. (1982) stated that in S. hamate 25-58% and 31-58% yield reduction occurred in IRFL 7303 and IRFL 7413 genotypes respectively. Due to *Soybean mosaic virus* infection the highest yield reduction calculated for BINA Soybean-1 (38%). On the other hand, BINA Soybean-3 (25.83%) had the lowest yield reduction. Similar findings calculated by Mousanejad *et al*., (2010) and yield loss caused by SMV typically ranges between 8%-35% and in severe case may reach up to 100% (Ahangaran *et al.*, 2009)

There were negative relation found between disease incidence (%) of identified major diseases and yield (t/ha) of different soybean varieties which showed that with the increase of disease incidence (%) among the soybean varieties in identified major disease, yield of soybean decreased. A regression line was fitted between disease incidence (%) of major soybean diseases and yield of soybean. It resembles with the findings of Gupta (2000), Salihu, *et al*., (2019) conducted a study to determine extents of association among growth and yield contributing traits, disease incidence and severity.

CHAPTER V

SUMMARY AND CONCLUSION

Soybean (*Glycine max* (L.) Merrill) is one of the important oilseeds crops of the world, belongs to the family *Fabaceae*. More than 100 pathogens are known to affect soybean, of which 66 fungi, 6 bacteria and 8 viruses have been reported to be associated with soybean seed (Sinclair, 1978). For the fulfillment of the study purpose, rust of soybean (*Phakopsora pachyrhizi*), powdery mildew of soybean (*Microsphaera diffusa*), Anthracnose *(Colletotrichum truncatum), Soybean mosaic virus* were considered as the major diseases. Four popular varieties namely BARI Soybean-5, Shohag, BINA Soybean-1, BINA Soybean-3 with one Local (OP) were used in the experiment.

The aim of this study was to evaluate the varietal performance of soybean varieties against major diseases of soybean in field condition and to determine the disease incidence (%) and percent disease index of major diseases of soybean. The present piece of research work was placed in the central research field under Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November, 2018 to April, 2019. The experimental land was carried out with Randomized Complete Block Design (RCBD) plot design with three replications.

Results of this study focused on the performance of selected five varieties against major diseases in case of disease incidence (%), percent disease index (PDI), growth contributing characters like plant height (cm), average number of branches, average number of leaves, yield contributing characters such as Number of pods/plant, Number of Seed /pod, 100 seed weight (g), yield/plot (kg), yield (t/ha).

The major four diseases were prevalent on all the soybean varieties though the disease incidence and PDI level varied with the varieties. Disease incidence against rust of soybean highest in BINA soybean-1 (63.33%), lowest in BARI Soybean-5, against powdery mildew highest in BARI soybean -5 (83.83%) and

lowest in Local (OP) (56.66%) against anthracnose highest in Local (OP) (54.66%) and lowest in BINA soybean-1 (35.33%), against soybean mosaic disease highest in Shohag and Local (OP) (40%) and lowest in BINA Soybean-3 (20%)

Among five soybean varieties, one (BINA soybean-1) against rust, one (BARI soybean -5) against powdery mildew were found Highly Susceptible, four (BARI Soybean-5, BINA Soybean-3, Shohag, Local) against rust, four (BINA Soybean-3, Shohag, BINA Soybean-1, Local) against powdery mildew, four (BINA Soybean-3, Shohag, BINA Soybean-1, Local) against anthracnose were found Susceptible, four (BARI soybean -5, Shohag, BINA Soybean-1, Local) against soybean mosaic disease, one (BARI soybean -5) against anthracnose were found Moderately Susceptible, One (BINA Soybean-3) was found Moderately Resistant against soybean mosaic disease. There were no varieties found to be Resistant against these major diseases.

Negative relation was found between disease incidence (%) of identified major diseases and yield (t/ha). With the increase of disease incidence (%) among the soybean varieties in identified major disease, yield of soybean varieties decreased.

The results of the study on all growth and yield contributing characters including disease incidence showed significant reduction of growth and yield among the varieties due to disease infection. There were considerable yield reductions among the varieties due to disease infection from each of their recommended yield. None of the varieties had impressive tolerance against the diseases.

In view of the results the present study may be concluded as-

- The major four diseases were prevalent on all the soybean varieties though the disease incidence and PDI level varied with the varieties. Disease incidence against rust of soybean highest in BINA soybean-1 (63.33%), lowest in BARI Soybean-5 (40%), against powdery mildew highest in BARI soybean -5 (83.83%) and lowest in Local (OP) (56.66%) against anthracnose highest in Local (OP) (54.66%) and lowest in BINA soybean-1 (35.33%), against soybean mosaic disease highest in Shohag and Local (OP) (40%) and lowest in BINA Soybean-3 (20%)
- Among five soybean varieties one (BINA soybean-1) against rust, one (BARI soybean -5) against powdery mildew were Highly Susceptible, four (BARI Soybean-5, BINA Soybean-3, Shohag, Local) against rust, four (BINA Soybean-3, Shohag, BINA Soybean-1, Local) against powdery mildew, four (BINA Soybean-3, Shohag, BINA Soybean-1, Local) against anthracnose were Susceptible, four (BARI soybean -5, Shohag, BINA Soybean-1, Local) against soybean mosaic disease, one (BARI soybean -5) against anthracnose were Moderately Susceptible, One (BINA Soybean-3) was Moderately Resistant against soybean mosaic disease.
- There were significant reduction of different growth and yield contributing characters due to disease infection among the soybean varieties. Among the varieties BINA Soybean-1 showed best yield performance.
- The yield of soybean varieties was found negatively correlated with the disease incidence and PDI of major diseases of soybean.
- Considering the disease incidence, PDI, growth and yield contributing characters among the soybean varieties it was evident that no resistant variety was found from this investigation. Whereas, BINA Soybean-1 and BINA Soybean-3 showed appreciable varietal performance.

RECOMMENDATION

BINA Soybean-1 and BINA Soybean-3 are recommended for the farmers as these two varieties showed the best varietal performance. This investigation was done under field condition at SAU research field (AEZ 28). If it could be done in different regions of Bangladesh or under controlled condition the results might be differed from this investigation. Considering all conditions, it can be recommended for further investigations.

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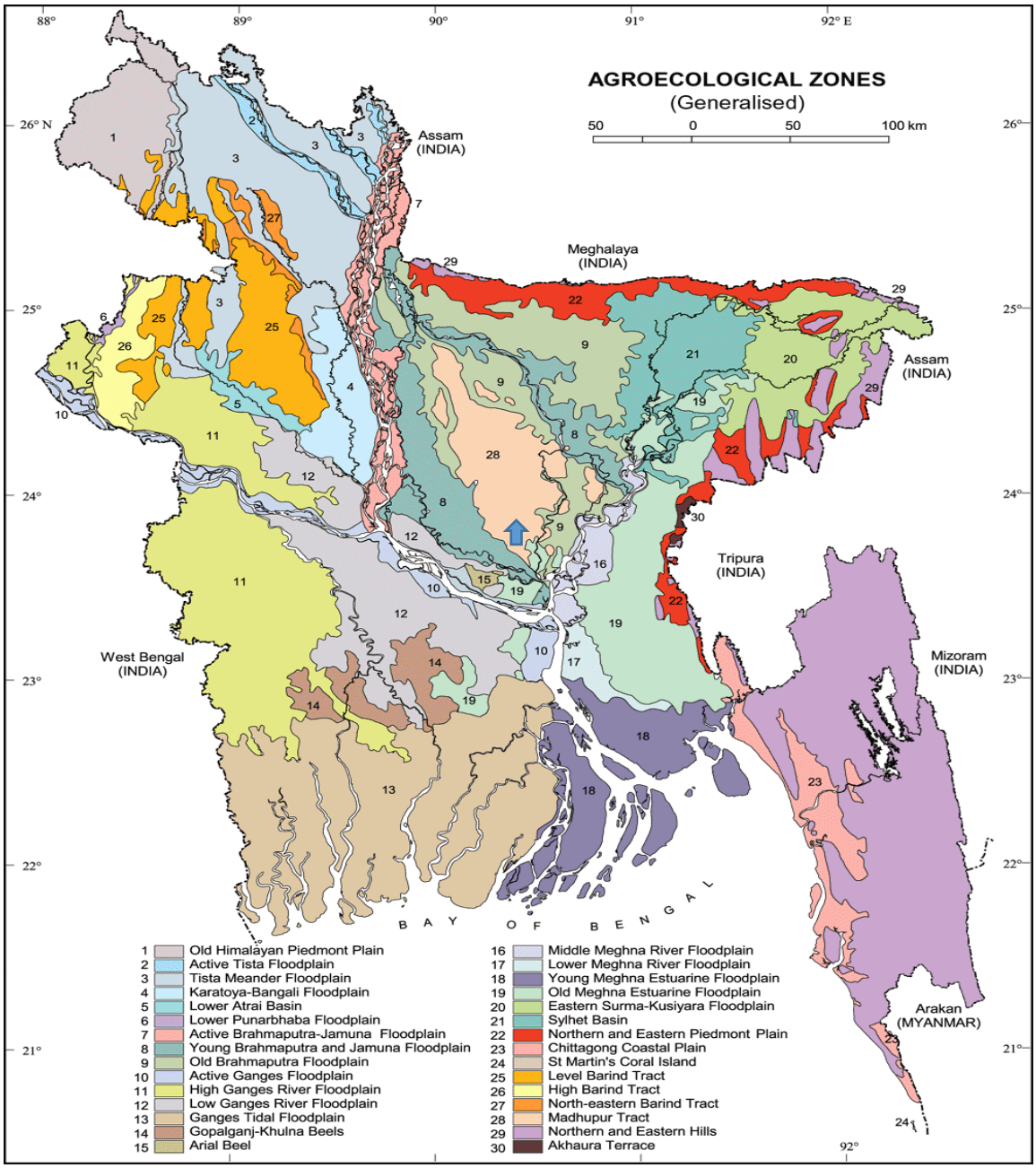
APPENDICES

Appendix I: Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II: Morphological and Chemical characteristics of soil of the experimental site as observed prior to experimentation

Morphological characteristics

Morphological features	Characteristics
Location	Experimental Field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium high land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Texture	Loamy

Chemical composition

Constituents	0-15 cm depth
P^H	6.00-6.63
Total N (%)	0.07
Available P (µ g/g)	18.49
Exchangeable K (µ g/g)	0.07
Available S (µ g/g)	20.82
Available Fe (µ g/g)	229
Available Zn (µ g/g)	4.48
Available Mg (µ g/g)	0.825
Available Na (µ g/g)	0.32
Available B (µ g/g)	0.94
Organic matter (%)	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka

Appendix III: Monthly meteorological information during the period from November, 2018 to April, 2019

Year	Month	Temperature (^{0} C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2018	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	00
2019	January	25.2	12.8	69	00
	February	27.3	16.9	66	39
	March	31.7	19.2	57	23
	April	33.50	25.90	64.50	119

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV: Different views of Soybean cultivation in experimental field

(A) Experiment field

(B) Individual plot

(C) Tagging plant for disease

(D) Healthy plant with pod

(E) Diseased plant

(F) During data collection