EVALUATION OF SELECTED SOYBEAN VARIETIES AGAINST SOYBEAN MOSAIC DISEASE

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EVALUATION OF SELECTED SOYBEAN VARIETIES AGAINST SOYBEAN MOSAIC DISEASE

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Dedicated

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My Beloved Parents

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CERTIFICATE

*This is to certify that the thesis entitled "***EVALUATION OF SELECTED SOYBEAN VARIETIES AGAINST SOYBEAN MOSAIC DISEASE***" 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,* **Registration No. 19-10292** *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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ABSTRACT

An experiment was conducted in the Central Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, to screen the resistant varieties of Soybean against *Soybean Mosaic Virus* (SMV) according to incidence and severity during the period from November 2020 to March 2021. Four soybean varieties viz. BARI Soybean-4, BARI Soybean-5, BARI Soybean-6, and Sohag, were used in this experiment by following RCBD design with three replications, data on following parameter viz. diseases incidence (%), severity (%), growth, yield, and yield contributing traits were recorded. There was significant variation found in all traits measured in field. In case of disease incidence and diseases severity, the lowest disease incidence (22.23%) as well as diseases severity (10.65 %) were found in BARI Soybean-4 whereas the highest disease incidence and diseases severity (%) were also found in Sohag that were 27.17% and 12.79 % respectively. In case of growth characteristics like plant height, the number of branches plant^{-1} comprising the number of leaves, BARI Soybean-4 showed best performance over others where the highest number of leaves plant^{-1} was recorded from BARI soybean-4 (26.07). In the case of yield and yield attributing traits, the average range of pod number plant^{-1} varied from 25.40-43.20. Maximum pod number was recorded in BARI Soybean-4 (43.20) and maximum pod length (cm) was recorded in BARI Soybean-6 (3.38 cm). The highest number of seed pod^{-1} was recorded in BARI Soybean-5 (2.55) followed by the variety BARI Soybean-6 (12.56). The Maximum 100 seed weight was recorded in Sohag (12.24 g). The yield (t/ha) among the varieties ranges from 0.85 (t/ha) to 1.80 (t/ha). The maximum yield (t/ha) was recorded in BARI Soybean-6 (1.61 t/ha) and the minimum yield was also found in Sohag (1.23 t/ha). The highest yield reduction was found in Sohag (28.48%), on the other hand BARI Soybean-5 (12.88%) had the lowest yield reduction. There was a negative incidence and yield and positive relation between incidence and yield reduction. The performance of the variety BARI soybean-4 was much better than the other varieties against *Soybean Mosaic Virus* (SMV) in field whereas sohag showed worse performance against SMV.

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LIST OF ACRONYMS

Acronyms	**Full form**
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
et al.	And others
TSP	Triple Super Phosphate
MOP	Muriate of Potash
DAS	Days after sowing
g	Gram
Kg	Kilogram
Cm	Centimeter
%	Percentage
P^H	Potential of Hydrogen
CV(%)	Percentage of coefficient of variance
LSD	Least Significant Difference
V	Variety
^0C	Degree Celsius
RCBD	Randomized Complete Block Design
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 crop and belongs to the family Leguminosae and sub-family Papilionaceae. It is a new potential crop for Bangladesh and the most significant grain legume in the world (Ahangaran *et al.,* 2006). It is more appropriately categorized as an oil seed crop than a pulse (Ahmed *et al.,* 2013). It is one of the most well-known and significant protein- and oil-rich crops in the world.

The global production of soybeans is 337 million tonnes (USDA, 2018). In Bangladesh, it may be grown during both the Kharif and Rabi seasons, yielding 1.54 tons per hectare and producing a total of 97,000 tons on roughly 63000 hectares of land. (BBS, 2018). Each year, Bangladesh must purchase more than 1.5 billion USD to import 1.8 million tons of soybean cooking oil and 25.51 million USD worth of soybean meal (Alazem *et al.,* 2019).

About 60% of the weight of dried soybeans is made up of protein and oil, with protein making up 40% and oil 20%, respectively (Alimuddin *et al.,* 2002). The soybean is a fantastic source of essential nutrients, such as vitamins A, B, and D. It is also high in unsaturated fatty acids and minerals like calcium and phosphorus, which can help those who are deficient in certain nutrients (Amin 1968). Soybean has 3% lesithine which is helpful for brain development. (Azim *et al.,* 2019) depicted that unsaturated fatty acids, which don't raise blood cholesterol, make up 85% of soybean oil. The ideal ratio of necessary amino acids is present in soybean protein. It is considered a well-balanced protein food as a result. Due to its high nutritional content, soy products such as soymilk, soybean sprouts, soy nuts, various forms of tofu, cottage cheese, and curd are in higher demand (Babu *et al.,* 2008). High-quality protein and cholesterol-free oil (19.94%) are both provided by soybeans (36.49 percent). It is a rich source of lysine 7.3% (Babu *et al.,* 2008).

The health of soybean plants is seriously threatened by two significant groups of organisms: plant pathogenic fungus and viruses. Plant pathogenic fungi can alter seed composition and reduce yield in addition to reducing output (McKern *et al.*, 1992). One of the most severe, damaging, and pervasive diseases of *Glycine max* is *Soybean mosaic disease* (SMD). With its limited host range, SMV only infects six plant families: Fabaceae, Amaranthaceae, Chenopodiaceae, Passifloraceae, Schrophulariaceae, and Solanaceae. *Glycine soja* and *Glycine max* are both frequent hosts for the parasite, and the Potyvirus genus is the most diversified in the world of plant RNA viruses with 160 species (Sandra *et al.,* 2015). Only the soybean mosaic potyvirus has been observed to result in yield losses of up to 93% and 50% in experimentally infected plants. The plants that have been infected can occasionally die. Foliar symptoms can range from minor leaf mottling to severe leaf deformation, necrosis, and general stunting. The majority of infections happen after flowering and barely affect seed quality or yield (Camelo-Garcia *et al.,* 2021). SMV is a virus that spreads through seeds and aphids. Depending on the virus genotype and soybean variety, seed transmission rates range from 0% to 64% (Gazala *et al.*, 2013).

The virus may cause more than 90% yield loss (Gunduz *et al.*, 2004). Kulkarni first reported that the virus was first identified in 1942 as a damaging soybean infection that was common in the Indian city of Bombay. Later, other Indian scientists thoroughly investigated and described the virus (Zhang *et al.,* 2022b). *Soybean mosaic virus* (SMV) is the most important one as reported by (Nutter *et al.*, 2020). In the soybean plant, *Glycine max* (L.), gets infected with the *Soybean mosaic virus* (SMV), which can result in yield decreases of up to 35% (Chen *et al.,* 2015). SMV has been reported worldwide in all soybean-growing areas (Chen *et al.,* 2004) and is a member of the genus Potyvirus (family Potyviridae), one of the largest genera of plant viruses (Chen *et al.,* 2001). Due to the lack of other hosts for the virus in North America, SMV-infected seeds are the main source of inoculum in the field (Chen *et al.,* 2017). Due to a striking alteration in the cellular components of the infected plants, the virus appears to attack soybean plants at any stage of plant growth, spreads swiftly in the field, and negatively impacts the growth and yield-contributing qualities (Wang *et al.,* 2006).

In Bangladesh, no comprehensive research on the *Soybean mosaic virus* has yet been conducted. There have been rare reports of research to find resistant varieties or preventative measures Most of the research carried out in Bangladesh to date has been of the disease survey kind, which included the disease name, field symptoms, and testing plant types against the illness in their natural environments (Chowda-Reddy *et al.,* 2011).

Bangladesh needs to import 1.20 million metric tons of edible oil annually at a cost of around Tk 40 billion to meet its increasing demand due to the yield losses brought on by the attack of the *Soybean mosaic virus* (Babu *et al.,* 2008, Rahim *et al.,* 2020). Thus, it has been given top priority when choosing soybean lines for high production and resistance to viral diseases. Bangladeshi agricultural studies have demonstrated the effectiveness of soybean production techniques in the districts of Noakhli and Laxmipur (Rahim *et al.,* 2020).

Good agricultural practices and the development of resistant cultivars through breeding and genetic engineering are the main methods used to control SMV (Kumar *et al.,* 2015). In the East Java province, soybeans that are vulnerable to SMV have shown yield reductions of 15–35%. One barrier to the adoption of new soybean cultivars is a mosaic disease (Khatabi *et al.,* 2012). For boosting domestic soybean output, better cultivars with high yield and SMV resistance are required. Therefore, various initiatives to boost soybean production had been made, but there were still obstacles in the way of their execution, particularly the viral infection, which had not yet been dealt with appropriately (Khatabi, *et al.,* 2013).

A technique that is low-cost and simple to execute is the genetic enhancement of SMV resistance with a high yield. New soybean cultivars play a crucial and strategic role in efforts to boost productivity. By using resistant cultivars, one might ensure yield stability as environmental conditions change (Kim *et al.,* 2016). Planting SMV-resistant cultivars is thought to be the most effective and environmentally safe way to control the disease. However, there are currently no soybean cultivars that are resistant to SMV (Rani *et al.*, 2017). Numerous biotic and abiotic stressors affect the soybean crop. *Soybean mosaic virus* (SMV) is the most divesting disease of soybean among the several biotic stressors. (Manik *et al.*, 2009). A plant's normal physiological and morphological processes are necessary for its growth and development. The pathogen may cause the infected plant's physiological and morphological processes to change. There are reports of biochemical alterations caused by virus infection in numerous crops other than soybean (Paris *et al.,* 2006). Information regarding virus infection causing tremendous yield losses of soybean is available (Kim *et al.,* 2004).

Considering the facts, the research program was designed with the following objectives-

- To evaluate selected soybean varieties against *Soybean mosaic virus* (SMV) at field condition
- To assess the disease incidence and severity of *Soybean mosaic virus* (SMV) among selected varieties
- To find out the correlation between yield characteristics and diseases

CHAPTER II

REVIEW OF LITERATURE

Soybean is a major oil seed crop in the world (Koning *et al.*, 2003). It is utilized for therapeutic, industrial, and dietary purposes. It is often referred to as the world's miracle crop. Foliar infections, on the other hand, pose harm to the crop. They either directly contribute to yield loss or have an impact on seed quality (Amrate *et al.*, 2018). Utilizing various disease-resistant genotypes as a management method significantly reduces the losses brought on by diseases. There isn't a lot of material available about the different disease-resistant genotypes of soybean. Therefore, an effort was made to gather the pertinent reviews for the current inquiry in this chapter.

2.1. Nutrition of soybean

Koning *et al.* (2002) stated that leguminous soybean (*Glycine max* L. Merr.) is a crop that is a strong source of both vegetable oil and protein. It can be quite important in balancing the lack of protein in our diet. These legumes include a significant amount of plant-based protein that is safe for consumption.

Bao *et al.* (2018) stated that because it has replaced other sources of plant oil and protein as the primary source, soybean (*Glycine max* L. Merrill) is regarded as a strategic crop on a worldwide scale. (Lamprecht *et al.,* 2010) stated that because of its symbiotic relationship with rhizobiam and consequent fixation of N_2 from the air, soybean may meet up to 80% of its nitrogen needs. (Chen *et al.*, 2017) described that comparing the host range, symptomatology, and serology of two SMV isolates that cause mild symptoms in one cultivar (Essex) and severe symptoms in another (Electron microscopy of soybeans) infected with two isolates of *Soybean mosaic virus*.

2.2. Characteristics of *Soybean Mosaic Virus* (SMV): Symptoms

The leaves of soybeans with SMV infection display a mosaic pattern of colors. This mosaic is subtler in some cultivars than those caused by several other soybean viruses. The second type of color patterning that can be seen in plants with SMV infection is a small, darker green band along the veins and a lighter green lamina in between the veins. Not all soybean cultivars have this vein banding, but some cultivars can be distinguished by it (Li *et al.*, 2022).

It is also common to see leaf shape deformation or lamina distortion, particularly when the leaves curl downward. On infected plants, stunting also takes place. Infected soybean seed exhibits extensive seed mottling due to SMV (Li *et al.,* 2009). There is also color leakage from the seed hilum, similar to that seen with SMV, but it is frequently darker than that brought on by SMV.

2.3 Causal agent

SMV (Genus: Potyvirus; Family: Potyviridiae) is a long, flexuous rod virus approximately 15 nm by 750 nm (Rehnuva *et al.*, 2006). The single-stranded RNA genome of this virus is tightly wound inside the particle and plays a crucial function in keeping the particle together. Thus, unlike some icosahedral viruses, like SMV, which can assemble the protein coat into a particle before RNA is introduced, these particles do not form unless the RNA is present (Chen *et al.*, 2017).

2.4. Vectors

More than 16 different aphid species are known to transmit SMV, with the soybean aphid (*Aphis glycines*) serving as the main vector (Hong *et al.*,, 2003). The soybean aphid's appearance has given SMV a plentiful vector for transmission (Balgude *et al.,* 2012). Aphids spread SMV in a non-persistent manner (Kumar *et al.,* 2022). This indicates that the aphids can quickly pick up or spread the virus. Consequently, the aphid may spread SMV practically as quickly as it can fall on the soybean plant (Ohnishi *et al.,* 2011)

Raj *et al.* (2015) studied the relationship between disease incidence and population size of aphids in the crop sown. They observed a positive correlation between SMV incidence and the population size of aphids.

Sun *et al. (*2008) also studied on the efficiency of aphids in transmission of SMV in reciprocal inoculation tests of five different hosts. They reported that the maximum percentage of virus transmission occurred when the test and source plants were of the same species. Soybean and Urdbean were better test and source plants than French bean (*Phaseolus*) and pigeon pea for the virus and /or the vector. They also described that the virus transmission percentage increased with the increase in the number of adult aphids and that the nymphs were less efficient vectors than the adults.

According to (Rui *et al.,* 2017) SMV is transmitted by the aphids in a circulatory manner. Pre-acquisition and pre-inoculation starvation either increases the efficiency of transmission or has no effect.

Sandra *et al. (*2020) reported that the Yellow mosaic virus disease of a black gram [*Vigna mungo* (Linn.) Hepper] caused by soybean Yellow mosaic Geminivirus and transmitted by aphids (*Aphids Genn*.) is most serious in northern states of India, particularly, Bundelkhand Zone of Madhya Pradesh.

Sandra *et al.* (2021) studied the life history of the vector aphids, their maintenance, multiplication and dispersal on soybean and cotton, respectively. They found that the females laid 38-106 eggs in their total life span on the lower surface of leaves. The hatching “period was between 24 and 48 hours. The total life cycle from egg to adult stage ranged from 13 to 72 days.

Skopelitou *et al.* (2015) reported that the *Soybean mosaic virus* could be transmitted successfully by a single infectious Aphids but the maximum infection was given by

10 flies /plant. Infection was ensured when the vector had a pre-acquisition starvation period of 24 hours.

2.5 Mechanical transmission

The mechanical transformation approach can be used to spread the *Soybean mosaic virus*. In this procedure, a pH of 7.2 is maintained while first diluting the crude plant with a 0.01 M phosphate buffer. Before applying the inoculum of SMV, the testing of the leaf by 600 mesh carborundum is done. (Kumar *et al.*, 2022).

The soybean plant's wounded leaf is covered with inoculum to perform the inoculation. The inoculated plant is then placed in a greenhouse heated to 21°C (Li *et al.*, 2010). The incubation period is significantly influenced by temperature. Between an infection and the onset of symptoms, the duration spans from 4 days at 29.5°C to 14 days at 18.5°C (Yin *et al.*, 2021).

2.6 Insect transmission

Transmission by insects is a natural and important route of *Soybean mosaic virus* transmission. In the case of SMV, leafhoppers are the vectors of the virus. In this instance, the SMV-infected soybean plant is first fed upon by the leafhoppers (*Nephotettix nigropictus),* who then move on to the healthy soybean plant. The newly infected plant exhibits the same symptoms as those that were present in the previously infected plant where the leafhoppers (*Nephotettix nigropictus*) become virulent (Wei *et al.,* 2020). The incubation period between infection and the appearance of the septum is 4–14 days (Yang *et al.,* 2013).

Zhou *et al. (*2014) reported that SMV was observed to be transmitted nature by an insect vector belonging to the Aleyrodidae: Aphids in a nonpersistent manner. Helper virus was not required for transmission. The non-vector transmission was absent by mechanical inoculation, not by seed or pollen.

Zhou *et al.* (2015) reported that many isolates of SMV have been obtained from different hosts and regions in India which were transmitted by aphids but not by sap inoculation or through seeds. Isolates from Bangladesh, Pakistan and Srilanka have similar transmission characteristics. However, an isolate from Thailand was foundsap-transmissible.

2.7. The response of soybean genotypes against *Soybean mosaic virus* (SMV)

Yang *et al.* (2011) suggested a gene-for-gene model of the interactions between SMV and soybean. The different gene codes for Rsv1, Rsv2, and Rsv3 were assigned based on inheritance studies of SMV resistance in soybeans.

Amrate, *et al.* (2015) screened twelve varieties for resistance to SMV. Four varieties (Crow ford, Cico, Zane, and 80-B- 4007) were found resistant to the virus.

Wu *et al.* (2018) reported that the movement of more than 30 different aphid species, which may result in the secondary spreading of the virus, is one of the ways that SMV transmits in soybean fields in addition to from parent to progeny.

Zhang *et al.* (2022) conducted a study in view to check the infectivity of 36 genotypes evaluated on soybean plants in both natural and glass house environments for the *Soybean mosaic virus*. Out of 36 soybean genotypes screened in the field, two were found to be resistant to SMV (PS-1589 and PS- 1587), while seven were found to be moderately resistant (RSC-10-70, RVS- 2009-09, AMS-MB-5-19, SL-1104, MASC-1520, RSC-10-70, SL-1113, and JS-

9305).

Bao *et al.* (2018) evaluated 16 genotypes were examined, and it was discovered that 14 of the entries were completely resistant to the *Soybean mosaic virus*, while the other two displayed a highly resistant response.

Baruah *et al.* (2014) studied seven recommended varieties of soybean viz. 5 were tested to know the population dynamics of aphids under existing environmental conditions and its impact on the incidence of *Soybean mosaic virus* (SMV) disease and yield. He got 45% incidence there. The experiment was conducted at the farm of Sher-e-Bangla Agricultural University (SAU) Dhaka during the Kharif-I season (April to June) in 2006.

Chen *et al.* (2017) studied eighteen promising varieties of soybean for resistance to white fly aphids and Yellow mosaic virus and reported that the cultivar IPU-95- 13 showed high tolerance of *Yellow mosaic virus*. Among the 4 control cultivars, PU-35 performed well. T-9, a popular cultivar of the area was highly susceptible to aphids and *Yellow mosaic virus*.

Cho and Chung, (1976) reported NM98, NM-121-125, M-1, and NCM-209) was investigated against some sucking insect pests of soybean at the Gram Research Station Kalurkot, Bhakkar. Soybean varieties, NM-92 and NM- 98 showed significantly low mean aphids' population/leaf as compared to the other three tested varieties. A similar trend was also found among the varieties against jassids and thrips; however, the mean population/leaf of jassids and thrips in NM-98 and NM-121- 125 were statistically similar. Yield production of NM92 and NM-98 was significantly higher than the other tested varieties due to low infestation by sucking insect pests.

Cho and Goodman, (1979) investigated the resistance of Soybeancultivars (NM-92, NM98, NM-121-125, M-1, and NCM- 209) against some sucking insect pests evaluated in Kalurkot, Bhakkar, Pakistan. NM-92 and NM-98 showed significantly low mean aphids population per leaf than the other cultivars.

Choi *et al.* (2005) because of identifying resistance against *Soybean mosaic virus*, urban leaf crinkle virus and leaf curl virus in urdbean, evaluated 71 entries at NPRC, Vamban, Tamil Nadu. They found that RU 2229, VBG 86, 2KU 54, VBG 89, and SU16 were highly resistant to SMV.

Arogundade *et al.*, (2009) found that the genotypes, PLM 19, PLM 25, PLM 32, PLM 42, PLM 113, PLM 122, PLM 618, IC-1396-3, IC-2153, IC-43591,

EL-3902-A-EC-5551 and J-45 were resistant to Yellow mosaic virus, Cercospora leaf spot, and powdery mildew under field conditions.

Sun, *et al.* (2009) The lowest population of aphids (adult and nymph) was found in Barimung 6 as against the highest in Binamoog.

The population of aphids gradually increased with environmental temperature and relative humidity. However, the peak population was found at 32^0C and 80% relative humidity. The lowest percentage of SMV infected 15 plants were found in Barimung 6 and a positive relationship was found between the aphids population and the incidence of SMV disease. The highest yield of soybean was obtained from Barimung 6 and there was a strong negative relationship between the SMV infection and the yield of soybean.

Gbaporo *et al.* (2021) evaluated one hundred diverse stocks of black gram (*Phaseolus mungo* L.) for resistance against five different diseases widely prevalent in Himachal Pradesh. They found HPBU 38, HPBU 153, LBG 626 and UG 367 were resistant against Soybean Yellow mosaic and web blight.

Hong *et al. (*2003) screened the mung and red bean cultivars for growth components and yield against Yellow mosaic disease incidence. There was a reduction of 9.6 to 38.2 percent in height, 7 to 28.5 percent in fresh weight of shoot and 4.3 to 22.1 percent in dry weight, 25.7 percent in 1000 seed weight of susceptible cultivar. However, the germinability of seeds was unaffected due to the yellow mosaic.

Zhang *et al.* (2019) took up varietal screening for resistance against SMV at IARI, New Delhi, and reported that Jalgaon-781, T-2, Khargaon, and Mung local showed cent percent infection, however, Pusabaisakhi showed the least infection.

Alazem *et al.* (2019) evaluated 30 genotypes of soybean under field conditions for resistance of aphids Aphids, jassids Empoasca Kerri and YMMV. There were no significant differences among the genotypes MI-5, ML-803, DP91-249 and PMB-5. However, the genotypes were good sources of resistance against aphids, jassids, and YMMV and might be used as donor parents in breeding programs.

Yellow mosaic is reported to be the most destructive viral disease not only in Pakistan, but also in India, Bangladesh, Srilanka and contiguous areas of South East Asia (Arogundade *et al.*, 2009).

Abney *et al.* (1976) reported that there were 30 susceptible and 43 highly susceptible genotypes of soybean in their study. Great variation in genotype response to SMV represents variability in their genetic makeup.

Yang *et al.* (2013) described yellow mosaic virus as the most serious limiting factor in soybean and black gram cultivation and can attack the crop at any stage of growth, however, losses are severe when it attacks at an early stage. The total loss had been reported when the crop was infected by SMV within 1-2 weeks after germination. Yield loss, 63% and 20-30% losses were recorded at 3 and 4-7 weeks of age.

Yin *et al.* (2020) reported that the reduction in grain yield by SMV ranged from 39.9 to 51.5% in black gram varieties. They also observed that reduction in plant height, pods/plant, 100-seed weight and crop growth rate contributed to decreased grain yield.

Nam *et al.* (2009); Rani *et al. (*2017) assessed over six years, researchers examined the impact of temperature on the prevalence of the Hibiscus *Soybean mosaic virus* in six types of soybean. When compared to August, September had a higher incidence of SMV due to the lower temperature. Temperature and viral incidence were shown to have a strong negative connection. It was also clear that cultivars that had been virus-free in August began to exhibit virus signs in September. They discovered that the temperature affected SMV resistance, suggesting that a polygenic mechanism may be in charge of it.

About 100 percent of Bangladeshi soybeans are infected with the *Soybean mosaic virus* (SMV), which can result in yield losses of up to 90 percent as reported by (Rehnuva, Lapshina, Nagorskaia, Poliakova, & Lega, 2006). Using antisera from 20 different viruses, including the Soybean Yellow Mosaic Virus, he undertook ultrastructural analyses of the afflicted tissues and serology. He concluded that this virus might belong to the geminivirus group (Ramesh, Shivakumar, Praveen, Chouhan, & Chand, 2019).

Paris *et al.* (2006) conducted a field experiment was conducted in 1991 in Jorhat, Assam, India to determine the natural occurrence of the *Soybean mosaic virus* concerning various sowing dates. The soybean crop sown in May and June had the highest viral disease incidence (100%) while the crop sown in early October had the lowest incidence (16.7%). In the crops sown in February and March, the disease incidence was 36.5 percent and 54.2 percent, respectively.

A field experiment was conducted by (Rehnuva *et al.*, 2006) to find out the association between low aphid populations and high levels of *Soybean mosaic virus* during the 1988 and 1989 growing seasons. The first week of October in both years was the peak for the vector population. SMV symptoms were discovered to have started one week following an aphid infestation. The prevalence of the disease was shown to gradually rise along with the vector population. At 16 and 20 days following seed germination, adults of aphids and SMV signs were discovered. In the crops sown on February 26 and April 8, respectively, the viral incidence was 41 percent and 90 percent.

Zhang *et al.* (2019) recorded the severity index and the weekly incidence of the *Soybean mosaic virus* was compared. The severity measure showed the least amount of difference amongst the kinds. The most vulnerable variety, Pusa Sawani, saw a 100% infection rate, but HRB-9-2, DOV- 91-4, and Pashupati were at least field-tolerant to the virus.

Wang *et al.* (2011) studied that the yield loss model based on components like the number of pods per plant, the severity of disease, and stage of infection by SMV could predict yield loss very close to the actual loss in black gram. Of such a model would provide better estimates of losses due to the virus in different crops.

Paris *et al.* (2006) investigated that SMV infection affects grain yield when the plant has infection up to 50 days after planting. The color, texture, size and germination of the seeds were found to be affected. Yellow mosaic caused 16% yield loss in soybean and 10% yield loss (Fakir, 1983). Reduced plant height and fresh shoot weight were reported along with yield loss up to 66%.

K. H. Kim *et al.* (2016) observed that early infected plants had more severe symptoms than late infected ones. They also established that chlorosis, stunting and reduced branching contributed to yield loss. Ahmed (1985) observed 85% SMV incidence both in summer and winter pulse verities.

Y. H. Kim *et al.* (2004) observed that early infected plants had more severe symptoms than late infected ones. They also established that chlorosis, stunting, and reduced branching contributed to yield loss. Ahmed (1985) observed 85% SMV incidence both in summer and winter pulse verities. 13 percent was reported to be 100%; however, at 49 days old, the infection rate decreased to 31.70%. They discovered that as plants aged, the length of the virus's incubation period grew.

Wang *et al.* (2006) worked on the effect of the *Soybean mosaic virus* (SMV) on soybean growth and yield. Suhag is one of three types of soybean. To ascertain the impact of SMV infection on the growth and yield of soybean, kartica was grown in the field. Suhag, a virus-resistant cultivar, was shown to be less damaged by virus infection than the susceptible cultivars Vaishali Vadhu and kartica in terms of plant height, the number of leaves, pods/plant, pod length, and pod diameter.

Mishra *et al.* (2020) experimented to find out the rate at which soybeans are spread. The soybean varieties Tisuca (very vulnerable), Kartica (susceptible), and Seva are all affected by the soy mosaic virus (SMV) (resistant). 35 to 45 days after sowing was the time frame when disease development was at its highest (DAS).

Wang *et al.* (2011) studied each breeding line was planted in a block with its parents. Each line was planted in a 2 m by 3 m area with plants spaced 40 cm apart by 15 cm apart. Symptom monitoring and serological detection utilizing a double antibody sandwich enzyme-linked immunosorbent test were used to assess resistance to the SMV-T isolate (DAS ELISA). Mild, mosaic, necrotic, and symptomless reactions were some of the signs. 54 of the 56 soybean lines had an unfavorable reaction. The virus type that showed absorbance values less than two lines, namely (1) W/PI 200485-7-8 and (2) GK/Mlg 3288-7-11, was susceptible.

Soybean mosaic virus (SMV) is the content the name for the virus that infects soybeans and causes medically recognized symptoms, to account for all alternative names for the virus as reported by (Alazem *et al.*, 2019)

According to (Rahim *et al.*, 2020) 36 genotypes were evaluated to determine the *Soybean mosaic virus*'s ability to infect soybean plants in both natural and glasshouse environments. Out of 36 soybean genotypes tested in the field, PS- 1589 and PS-1587 were found to be resistant to SMV, whereas RVS2009-09, AMS-MB-5-19, SL-1104, MASC-1520, RSC-10-70, SL-1113, and JS-9305

were found to be moderately resistant. Out of nine promising genotypes that demonstrated resistance or escape in the field, glasshouse screening revealed that three genotypes (PS-1589, PS-1587, and SL 1104) showed a resistant reaction, one genotype (SL-1113) showed moderately resistant reaction, three genotypes (RSC-10-70, JS-9305, RVS-2009-09) were categorized as susceptible, and two genotypes (AMS-MB-5-19 and MASC-1520) showed moderately susceptible reaction.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted from November 2020 to March 2021 at the Sher-e-Bangla Agricultural University's central research field in Dhaka, Bangladesh. This chapter includes a brief explanation of the experimental site, climate, preparation of the soil and land, the layout of the experimental design, intercultural procedures, data recording, and data analysis.

3.1. The geographical location of the experimental site

The current study project was set up in the primary research area at the Sher-e-Bangla Agricultural University in Sher-e-Bangla Nagar, Dhaka, Bangladesh. The site was 8.2 meters above sea level and was situated at 23°74'N latitude and 90°35'E longitude.

3.2. Agro-Ecological Region of the experimental site

The experimental field was indeed a part of "The Modhupur Tract's" AEZ-28 agro-ecological zone. The Modhupur clay was used to create the complicated terrain and soils in this area. Flood plain sediments covered the Modhupur Tract's dissected borders, leaving little red soil hillocks that were bordered by the floodplain. The Map of Bangladesh's AEZ displays the trial site in **Appendix I.**

3.3. Characteristics of Soil

The trial area's soil was loamy and came from the Madhupur Tract, which was part of AEZ 28. The experimental plots' soil type was clay loam, and the fertility of the land was medium **(Appendix II).** The organic matter and nitrogen status of the soil were poor. The pH varied from 6.00-6.63.

3.4. Weather condition of the experimental site

The experimental site was a subtropical climate with three different seasons: the pre-18 monsoon period, also known as the hot season, which lasted at least from March to April, and the monsoon period, which lasts from May to October. The monsoon season lasts from November to February. The study was carried out between November 2020 and March 2021 **(Appendix III**).

3.5. Planting Material

For fulfilling the objective of the experiment four soybean varieties were selected as planting materials. They were collected from different source which was showed in table 1.

Table 1. Collection of the Soybean varieties along with their sources

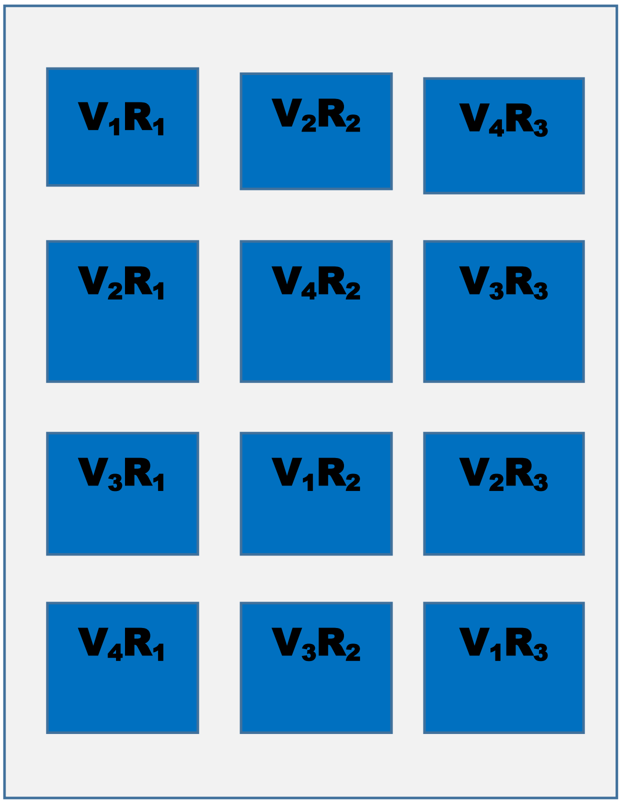
Variety	Source
Shohag	Bangladesh Agricultural Research Institute (BARI), Gazipur
BARI Soybean-4	Bangladesh Agricultural Research Institute (BARI), Gazipur
BARI Soybean-5	Bangladesh Agricultural Research Institute (BARI), Gazipur
BARI Soybean-6	Bangladesh Agricultural Research Institute (BARI), Gazipur

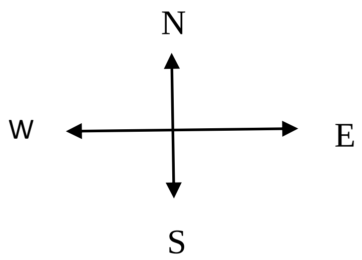
3.6. Land preparation

The experimental site's land was first made accessible using a powered tiller in November 2020. To achieve the desired condition, the field was afterward three times cross-ploughed and then laddered. After plowing and laddering all the stubbles and uprooted weeds were removed, and the ground was ready. The corners of the plot were spaded and larger clods were broken into smaller pieces.

3.7. Design and layout of the experiment

Three replications of the Randomized Complete Block Design (RCBD) plot design were used for the experimental site. The total numbers of unit plots were 12. The size of the unit plot was 4.0×3.0 m^2. The distances between plot to plot and replication to replication were 0.50 m and 0.75 m, respectively. The design was completed on November 27, 2020





Layout

Plot size: 4.0 m × 3 m^2

Between plot: 0.5 m

Between block: 1 m

Between replication: 0.75 m

Figure 1. The layout of the experimental field

Treatments

V_1 – Sohag

V_2 – BARI Soybean-4

V_3 – BARI Soybean-5

V_4 – BARI Soybean-6

3.8. Seed sowing

Seeds were sown on 4th December, 2020 continuously in 30 cm apart rows opened by hand hoe. After sowing, the seeds were covered with soil and slightly pressed by hands.

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 of $144m^2$. All fertilizers were applied during the final land preparation.

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

Intercultural operations

3.10.1. Thinning

Seeds germinated 10 days after sowing (DAS). After germination, thinning was performed twice; the first time was at 20 DAS, and the second time was at 40 DAS. This was done to achieve the proper plant population in each plot while maintaining the 5–6 (cm) plant-to-plant distance.

3.10.2. Weeding

Three weddings were performed on the agricultural field: the first at 15 DAS, the second at 35 DAS, and the third at 70 DAS.

3.10.3. Irrigation and drainage

The first irrigation was done at 20 DAS. Second irrigation was provided at 55 DAS. A proper drainage facility was also provided for draining out excess water.

3.10.4. Disease and pest management

The experimental crop was infested by hairy caterpillars (*Diacrisia obliqua*) and cutworms at the early growth stage, which were controlled by applying Sumithion 50 EC @1.0 L ha-1. Hand-picking of infested leaves was also done as a control measure. Diseased or off-type plants were uprooted as and when required but these were not recorded.

3.11 Identification of virus and disease incidence of *Soybean mosaic virus* (SMV)

Based on studying typical symptoms of SMV were described by Capoor and Verma (1955), Begum (2002) and Hossain (1998). The soybean plants were inspected every day until harvest and the symptoms appeared in the soybean plants was noted.

The growth stage of the plants was categorized as follows-

1) Early stage - 5 weeks after seed sowing

2) Mid stage - 5 weeks after early stage, and

3) Late stage - after mid stage up to harvest.

4) The disease incidence was expressed in percentage on the basis of stage as well as total i.e., average of three stages.

(A)

(B)

(C)

Plate 1. Symptoms of SMV at different stage (A. Infected plant Early stage B. Infected plant late stage, C. Healthy plant leaves).

3.12. Data collection

Five plants from each variety were randomly selected. The collected parameters during field experiments were:

1.Plant height (cm)
2.Number of leaves/plant
3.Number of branches/plant
4.Number of pods/plant
5.Pod length (cm)
6.Number of seeds /pods
7.100 seed weight (g)
8.Disease incidence (%)
9.Percent Disease Index
10.Yield t/ha

3.13. The procedure for recording growth data

3.13.1. Plant height (cm)

The height of the soybean plants was measured starting at 60 days after sowing (DAS) and every 15 days until 90 DAS and the time of harvest. From the bottom of the plant up to the tip of the top leaf, the height of the plant was measured. For each plot, the plant height was determined by averaging the heights of five randomly chosen healthy plants.

3.13.2. Number of leaves/ plant

The total number of leaves/plant was taken from 60 DAS at 15days intervals up to 90 DAS and at harvest. The average number of leaves/plant of five plants was considered as the number of leaves per plant for each plot.

3.13.3. Number of branches/plant

The total number of branches/plants was taken from 60 DAS at 15days intervals up to 90 DAS. The average number of branches/plants of five plants was considered as the number of branches plant-1 for each plot.

3.14. The procedure of collecting data on yield and yield components

For assessing yield parameters data were collected from 5 randomly selected plants from each of the plots. For measuring seed and straw yield, an area of 1.0 m^2 from the center of each plot was harvested.

3.14.1. Number of pods/plant

The number of pods/plants was recorded from randomly selected 5 plants on each plot. Data were recorded at harvest time. Mean data were expressed in numbers. The number of pods/plants was measured by hand counting at 5 days' intervals from 60 DAS to 90 DAS.

3.14.2. Pod length (cm)

The length of the pod was measured by using a meter scale. The measurement was taken from the base to the tip of the pod. The average length of the pod was taken from five randomly selected pods from randomly selected plants on each plot. Data were recorded at harvest time. Mean data were expressed in centimeters (cm).

3.14.3. Number of seeds/pod

Data on the number of seeds/pod was counted. Five plants were randomly selected and the average data were collected from the inner rows of each plot except the harvest area during the time of harvesting.

3.14.4. Weight of 100 seeds (g)

One thousand cleaned dried seeds were randomly collected from the seed stock of each plot and were sun-dried properly. These dried seeds were weighed using an electric balance and the weight was expressed in gram.

3.14.5 Yield (t/ha)

The yield was calculated obtained from each plots after harvesting from each plot (kg) according to replication based yield that were converted into hectare base.

The yield was calculated by the following formula:

$$\frac{\textbf{Total yield of each plot (kg)} \times \mathbf{10000}}{\textbf{Area of the each plot (m2)} \times \mathbf{1000}}$$

3.15. Disease incidence (%)

Disease incidence (%) of *Soybean mosaic virus* was measured under natural infection by using the following formula (B. Kumar *et al.,* 2014)

$$\text{Disease incidence (\%)} = \frac{\mathbf{X_1}}{\mathbf{X}} \times \mathbf{100}$$

Where,

X= Total number of plants

$\mathbf{X_1}$ = Number of infected plant

Plants that did not show any symptoms developed by the virus i.e. remained asymptomatic up to the last harvest were considered healthy resistant plants. If it is not otherwise stated, the stage of infection was only interpreted for the prevalence study of the virus.

3.16 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 the 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

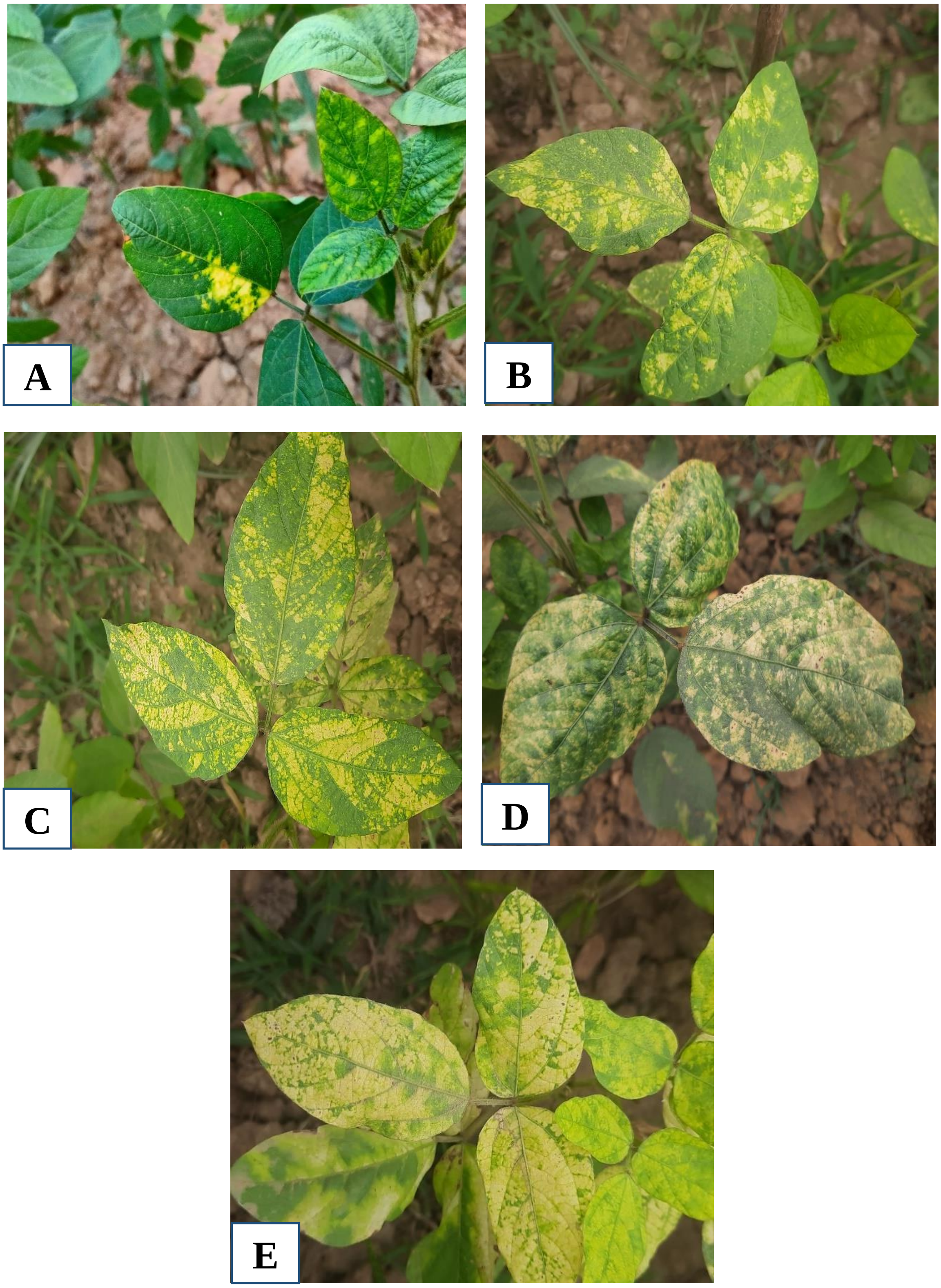


Plate 2. The photographs indicate several scale of diseases severity (%) of *Soybean mosaic virus*. Here, A. expresses (0 - 20%), B. (20 - 40%), C. (40 - 60%), D. (60 - 80%) and E. also narrates (80 - 100%).

3.17 Disease severity (%)

Disease severity was rated using 10 randomly pre-tagged soybean plants in the three central rows, using standard disease scales of 1-5 disease severity, where, 1 = 1 - 10%, 2 = 11 - 25%, 3 = 26 - 50%, 4 = 51 -75%, and 5 = 76 - 100% of the leaf surface (Koike *et al.*, 2001) and average severity of the 10 plants per plot was used for statistical analysis. The scores were changed into percentage severity index (PSI) for analysis using the formula as follows (Wheeler, 1969).

The disease severity of soybean was determined by the following formula (Manandhar, 2016):

$$\text{Disease Severity (DS) \%} = \frac{\textbf{Total point score}}{\textbf{Total no of plant}\times\textbf{maximum grade}} \times 100$$

3.18. Statistical analysis

The data was illustrated as mean ± standard deviation from three independent analyses. One-way analysis of variance (ANOVA) was accomplished at the level of significance $P \leq 0.05$, according to the randomized complete block design (RCBD), the stage of development and ripening, and replicates as the main factors to identify if varieties were significantly different from each other for the traits. The analysis of variance of the different morphological and yield attributing parameters, Tukey's pairwise comparison, was conducted by using the Minitab 17 statistical software package (Minitab Inc., State College, PA, USA)

CHAPTER IV

RESULTS AND DISCUSSION

This chapter includes the experimental results. Four varieties viz. Sohag, BARI Soybean-4, BARI Soybean-5, and Soybean-6, were assessed against *Soybean Mosaic Virus* (SMV) in field conditions. Results were compiled based on growth data as well as yield and yield attributing traits on different days after sowing (DAS) presented in this chapter.

4.1. Disease incidence (%) of *Soybean Mosaic Virus* (SMV) among selected varieties at 60, 75, and 90 DAS

No significant variation was found in disease incidence (%) at 60 and 75 DAS among tested varieties. But there was significant variation found among varieties in SMV incidence at 90 DAS $p < 0.01$. The results of percent disease incidence at 60, 75 and 90 DAS are presented in **Table 2.**

At 60 DAS, the difference between highest and lowest disease incidence (%) was recoded 9.58(%). The highest disease incidence (%) was recorded from BARI soybean-6 (17.78 %) whereas the lowest disease incidence (%) was found in Sohag (8.21%).

Almost similar ratio was obtained on 75 DAS. At 75 DAS, the highest disease incidence (%) was also recorded from BARI soybean-6 (20.2 %) while the lowest disease incidence (%) was found from BARI soybean-5 (15.55%)**.**

In the case of 90 DAS, the highest disease incidence (%) was recorded from Sohag (27.17%) which was significantly different from the varieties BARI soybean-4 (22.23%) and BARI soybean-6 (22.48%) followed by the variety BARI soybean-5 (25.31%) whereas the lowest disease incidence (%) was also found in BARI soybean-4 (22.23%)**.**

Table 2. Disease incidence (%) of *Soybean Mosaic Virus* (SMV) among selected varieties at 60, 75 and 90 DAS

Variety	Disease incidence (%)		
	At 60 DAS	**At 75 DAS**	**At 90 DAS**
Sohag	8.21	12.20	27.17 a
BARI Soybean-4	11.11	17.10	22.23 bc
BARI Soybean-5	8.89	15.55	25.31 ab
BARI Soybean-6	17.78	20.02	22.48 ab
CV%	46.92	49.23	6.21
Level of Significance	$p > 5\%^{NS}$	$p > 5\%^{NS}$	$p < 1\%^{**}$

Figure in the column, NS narrates Non-Significant at 5% level of significance, **= Significant at 1% level of significance. CV% means Co-efficient of Variation, Here, DAS: Days after sowing.

4.2. Disease severity (%) of *Soybean Mosaic Virus* (SMV) among selected varieties at 60, 75, and 90 DAS

Significant variation was found among the varieties for disease severity (%) at 90 DAS. But there was no significant variation found among varieties in SMV incidence at 60 and 75 DAS. The results of percent disease severity (%) at 60, 75, and 90 DAS are presented in **Table 3.**

At 60 DAS, maximum disease severity (%) was recorded from Sohag (6.11%) whereas the minimum disease severity (%) was found from BARI soybean-5 (1.45%).

At 75 and 90, DAS showed the reverse result of disease severity (%) than 60 DAS. The maximum disease severity (%) was recorded from BARI soybean-6 (7.87%), while the minimum values were recorded from BARI soybean-5 (3.87%).

On the other hand, In the case of 90 DAS, Significant variation was found among the varieties at $p < 0.01$. The maximum disease severity (%) was recorded from BARI soybean-5 (18.13%) which is significantly different from all the varieties

BARI soybean-6 (14.29%) and Sohag (12.79) was followed by the variety BARI soybean-4 (10.65%)

Table 3. Disease severity (%) of Soybean Mosaic Virus (SMV) among selected varieties at 60, 75 and 90 DAS

Variety	Disease severity (%)		
	At 60 DAS	At 75 DAS	At 90 DAS
Sohag	6.11	7.63	12.79 b
BARI Soybean-4	3.69	6.72	10.65 c
BARI Soybean-5	1.45	3.87	18.13 a
BARI Soybean-6	4.36	7.87	14.29 b
CV%	73.50	53.02	7.21
Level of Significance	***p*** > 5% NS	***p*** > 5% NS	***p*** < 1%**

Figure in the column, NS narrates Non-Significant at 5% level of significance, ** = Significant at 1% level of significance. CV% means Co-efficient of Variation, Here, DAS: Days after sowing.

4.3 Comparison between disease incidence (%) and disease severity (%) among soybean varieties at 60, 75, and 90 DAS

Comparison between disease incidence (%) and disease severity (%) among soybean varieties at 60, 75, and 90 DAS are shown in figure 2.

At 60 DAS, in case of disease incidence, BARI Soybean-6 (17.78) had the highest incidences whereas disease severity Sohag (8.21) showed the highest value.

At 75 DAS, both disease incidence (%) and disease severity (%) BARI Soybean-6 (20.02) had the highest value.

But at 90 DAS, Sohag (27.17) showed the maximum value in the case of disease incidence whereas a little bit change in disease severity. At 90 DAS. BARI Soybean-5 (25.31) disease severity (%) showed the maximum value

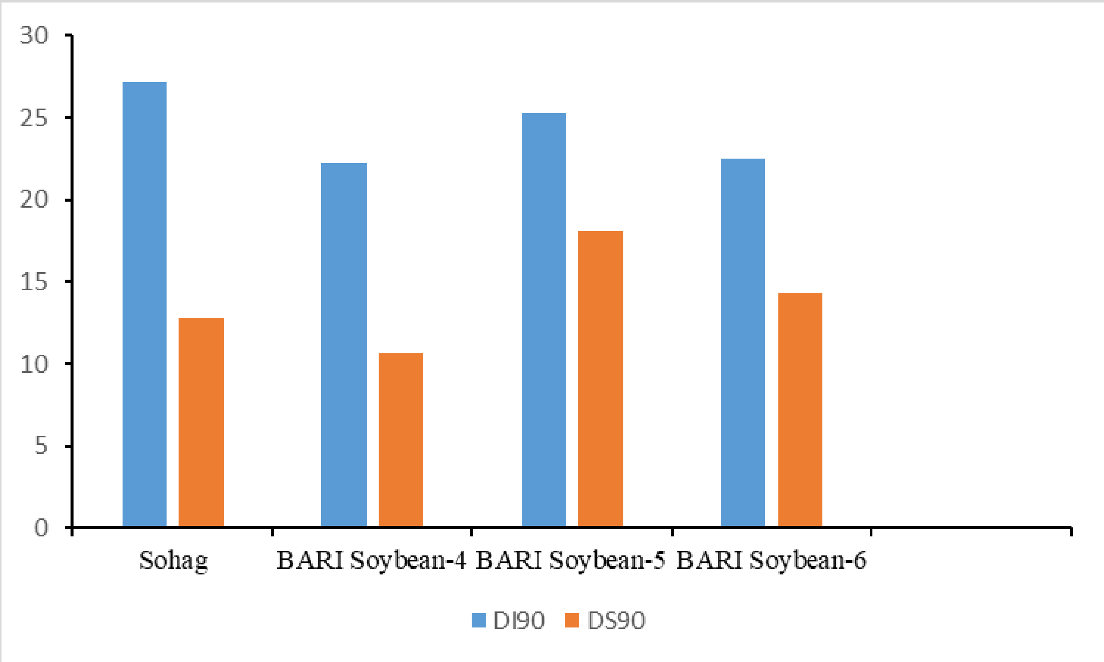


Figure 2. Disease severity (%) and incidence (%) of soybean varieties at 90 DAS. Here, DAS: Days after sowing. DI denotes disease incidence (%) where DS narrates disease severity.

4.4. Effect of *Soybean Mosaic Virus* (SMV) on Growth attributing traits at different DAS

Growth attributes viz. plant height (cm), number of branch per plant and number of leaves per plant showed significantly differ among different varieties at 60, 75 and 90 DAS. The results of all growth attributes are shown in **Table 4, 5, 6.**

4.4.1 Plant height (cm)

Significant variation was found among the varieties for plant height at 60 DAS **($p < 0.05$)**. But there was no significant variation found among varieties in SMV incidence at 75 and 90 DAS. The results of at 60, 75, and 90 DAS are presented in **Table 4.**

At 60 DAS, among the four varieties, BARI soybean-6 showed the highest plant height (22.78 cm) which was different from the other varieties while BARI soybean-4 showed the lowest height (18.98 cm). The rate of increase in plant height was higher from 60 DAS to 75 DAS, after that the values of plant height increased the same as before up to 90 DAS and the highest plant height was attained at this stage for all four varieties.

At 75 DAS gave the highest plant height was found in BARI soybean-5 (34.41 cm) and lowest plant height was found in Sohag (29.04 cm).

At 90 DAS BARI soybean-5 gave the highest plant height, (41.82 cm) and lowest plant height was found in Sohag (38.97 cm).

Table 4. Plant height of different soybean varieties on (cm) at 60, 75 and 90 DAS

Variety	Plant height (cm)		
	At 60 DAS	At 75 DAS	At 90 DAS
Sohag	22.18 ab	29.04	38.91
BARI Soybean-4	18.98 b	32.13	40.97
BARI Soybean-5	20.73 ab	34.41	41.82
BARI Soybean-6	22.78 a	32.27	39.31
CV%	7.62	10.36	4.14
Level of Significance	$p < 5\%^{*}$	$p > 5\%^{NS}$	$p > 5\%^{NS}$

Figure in the column, having the same letter(s) does not differ significantly at 5% level of significance. *= Significant at 5% level of significance, **= Significant at 1% level of significance analyzed by Tukey Test. NS narrates Non-Significant, CV% means Co-efficient of Variation, Here, DAS: Days after sowing.

4.4.2 Number of branches plant^{-1}

Statistically, non-significant variation was recorded for the number of branches plant^{-1} of soybean at 60,75 and 90 DAS respectively. The results of percent disease severity (%) at 60,75 and 90 DAS are presented in **Table 5.**

At 60 DAS, the maximum number of branches plant^{-1} was recorded from BARI soybean-5 (3.07) whereas the minimum number of branches plant^{-1} was found from Sohag (2.26).

At 75 DAS, the maximum number of branches plant^{-1} was recorded from BARI soybean-4 (6.17) and the minimum values were recorded from BARI soybean-6 (5.48).

At 90 DAS, the maximum values of number of branches plant^{-1} were recorded from BARI soybean-5 (13.11) while Sohag (9.79) consisting the minimum number of branches plant^{-1}.

Table 5. Effect of soybean variety on number of branches plant^{-1}

Variety	Number of branches/plant		
	At 60 DAS	At 75 DAS	At 90 DAS
Sohag	2.26	5.71	9.79
BARI Soybean-4	2.67	6.17	9.98
BARI Soybean-5	3.07	5.82	13.11
BARI Soybean-6	2.9	5.48	11.50
CV%	10.18	12.24	11.05
Level of Significance	p > 5% NS	p > 5% NS	p > 5% NS

Figure in the column, NS narrates Non-Significant at 5% level of probability. CV% means Co-efficient of Variation, Here, DAS: Days after sowing.

4.4.3 Number of leaves plant^{-1}

Significant variation was found among the varieties for number of leaves plant^{-1} at 90 DAS. But there was no significant variation found among varieties in SMV incidence at 75 and 90 DAS. The results of percent disease severity (%) at 60, 75, and 90 DAS are presented in **Table 6.**

At 60 DAS, the highest number of leaves plant^{-1} was recorded from BARI soybean-6 (8.09) and the minimum number of leaves plant^{-1} was found from BARI soybean-4 (7.54).

At 75 DAS, the maximum number of leaves plant^{-1} was recorded from BARI soybean-4 (17.57) and the minimum values were recorded from BARI soybean-6 (15.57).

On the other hand, In the case of 90 DAS, Significant variation was found among the varieties at $p < 0.01$. The maximum number of leaves plant^{-1} was recorded from BARI soybean-4 (26.07) which is significantly different from the varieties Shohag (22.17) and BARI soybean-6 (21.24) followed by the variety BARI soybean-5 (24.80).

Table 6. Effect of soybean variety on number of leaves plant^{-1}

Variety	Number of leaves/plant			Reaction
	At 60 DAS	At 75 DAS	At 90 DAS	
Sohag	7.59	16.47	22.17 bc	MR
BARI Soybean-4	7.80	17.57	26.07 a	MR
BARI Soybean-5	7.54	16.18	24.80 ab	MR
BARI Soybean-6	8.09	15.57	21.24 c	MR
CV%	14.68	10.88	12.43	
Level of Significance	***p*** > 5% NS	***p*** > 5% NS	***p*** < 1%**	

Figure in the column, having the same letter(s) do not differ significantly at 5% level of probability. *= Significant at 5% level of significance, **= Significant at 1% level of significance analyzed by Tukey Test. NS narrates Non-Significant, CV% means Co-efficient of Variation, Here, DAS: Days after sowing.

4.5. Effect of Soybean *Mosaic Virus* (SMV) yield and yield attributing traits

Yield attributes viz. Pod number plant^{-1}, Pod length (cm), Number of seed pod^{-1} and 100 seed weight (g) showed significantly differ among different varieties at 60, 75 and 90 DAS. The results of all growth attributes are shown in **Table 7.**

4.5.1. Pod number plant^{-1}

According to the study, pod number plant^{-1} in response to the *Soybean Mosaic Virus* of soybean showed substantial differences (p < 0.01) among the varieties **(Table 7).** The average range of pod number plant^{-1} varied from 25.40-43.20. Maximum pod number was recorded in BARI Soybean-4 (43.20) which was significantly different from the variety BARI Soybean-5 (35.22) and identically similar to the varieties BARI Soybean-6 (32.0) as well as Sohag (31.73) while the minimum number of pods plant^{-1} was recorded in BARI Soybean-5 (25.40), statistically similar with other varieties except for BARI Soybean-4 (43.20) **.**

4.5.2. Pod length (cm)

As indicated by the review, there was an enormous variation (p < 0.01) among the varieties **(Table 7).** Maximum pod length (cm) was recorded in BARI Soybean-6 (3.38 cm) which was significantly different from the variety Sohag (3.12 cm) and identically similar to the varieties BARI Soybean-4 (3.21 cm) as well as BARI Soybean-5 (3.37 cm) while the minimum pod length (cm) was recorded in Suhag (3.12 cm), statistically similar with BARI Soybean-4 (3.21 cm).

4.5.3. Number of seed pod^{-1}

In accordance with the review of the experiment, there was a tremendous fluctuation (p < 0.01) (**Table 7)** among the assortments. The maximum number of seed pod^{-1} was recorded in BARI Soybean-5 (2.55) which was followed by the variety BARI Soybean-6 (2.55), and BARI Soybean-4 (2.45), where they were statistically similar and significantly different from the variety Sohag (2.16). The minimum number of seed pod^{-1} was also found in Sohag (2.16).

4.5.4. 100 seed weight (g)

There was a huge contrast among the assortments (***p* < 0.01**) **(Table 7)**. The average range of 100 seed weight varied from 6.63 to 12.24 (g). Maximum seed weight was recorded in Sohag (12.24 g) followed by the varieties BARI

Soybean-5 (11.32 g) and BARI Soybean-6 (10.75 g) where they were statistically similar and significantly different from the variety BARI Soybean-4 (5.63 g). The minimum seed weight was also recorded in BARI Soybean-4 (5.63 g).

4.5.5. Yield (t/ha)

Yield (t/ha) of soybean varieties showed significant variation **(p < 0.01) (Table 7)**. The yield (t/ha) among the varieties ranges from 0.85 (t/ha) to 1.80 (t/ha). The maximum yield (t/ha) was recorded in BARI Soybean-6 (1.61 t/ha) which was followed by the variety BARI Soybean-5 (1.42 t/ha), and BARI Soybean-4 (1.32 t/ha), where they were statistically similar and significantly different from the variety Sohag (1.23 t/ha). The minimum yield (t/ha) was also found in Sohag (1.23 t/ha)**.**

Table 7. Effect of soybean variety on yield and yield attributing traits

Variety	Pod number/plant	Pod length (cm)	Seed number/pod	100 seed weight (g)	Yield (t/ha)
Sohag	31.73 ab	3.12 b	2.16 b	12.24 a	1.23 b
BARI Soybean-4	43.20 a	3.21 ab	2.45 a	5.63 b	1.32 ab
BARI Soybean-5	25.40 b	3.37 a	2.55 a	11.32 a	1.42 ab
BARI Soybean-6	32.00 ab	3.38 a	2.51 a	10.75 a	1.61 a
CV%	17.70	3.32	3.44	6.32	6.71
Level of Significance	p < 1%**	p < 1%**	p < 1%**	p < 1%**	p < 5% *

Figure in the column, having the same letter(s) do not differ significantly at 5% level of probability. *= Significant at 5% level of significance, ** = Significant at 1% level of significance analyzed by Tukey Test. NS narrates Non-Significant, CV% means Co-efficient of Variation.

4.6 Determination of yield loss among soybean varieties

Due to *Soybean Mosaic Virus* infection, the highest yield reduction was calculated in Sohag varieties (28.48%). On the other hand, BARI Soybean-5 (12.88%) **(Figure 3)** had the lowest yield reduction.

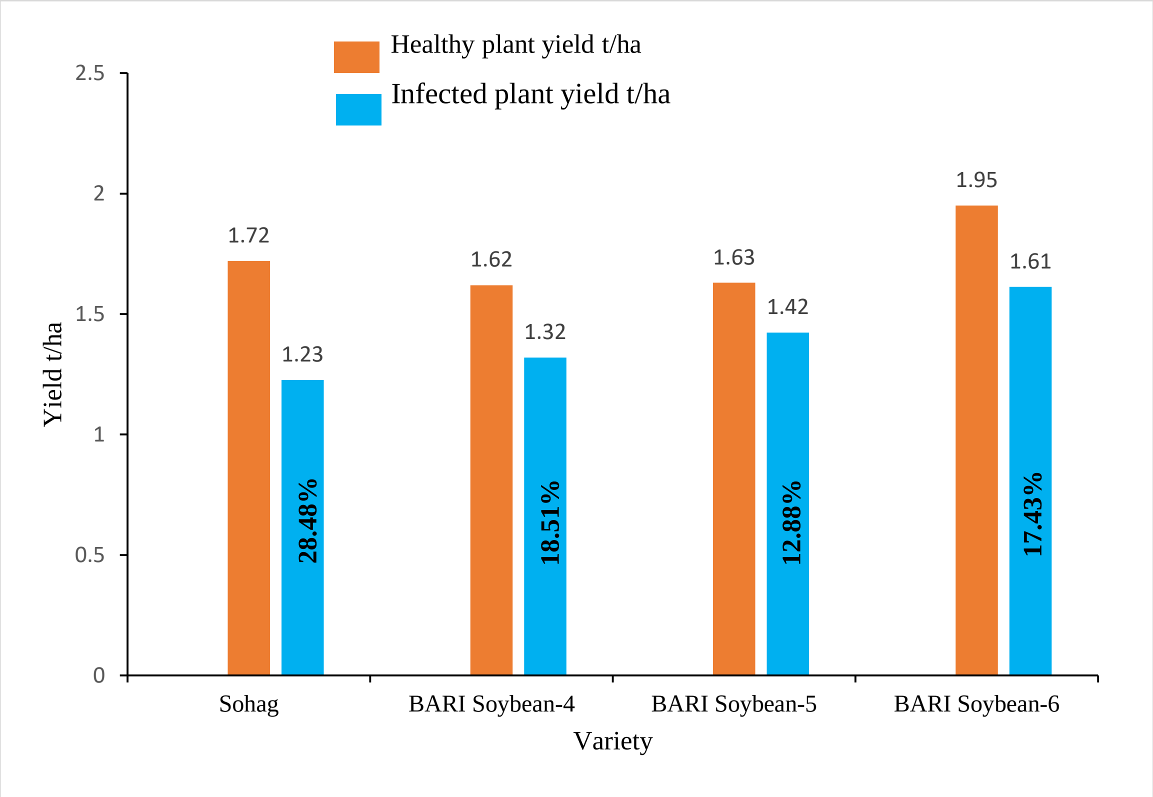


Figure 3. Yield of soybean varieties (t/ha) on the healthy plant in comparison with presentation plants respectively after harvesting where percentage denotes the yield loss.

4.7 Comparison of yield (expected and harvested yield) among soybean varieties

Minimum yield loss (24.14%) was recorded in BARI Soybean-4 variety compared with expected yield (t/ha) whereas maximum yield loss was found in Sohag (28.50%). The results are showed in table 8.

Table 8. Expected yield, harvested yield and yield loss and percentage of yield loss for selected soybean varieties

Variety	Expected yield (t/ha)	Harvested yield (t/ha)	Yield loss (t/ha)	Yield loss (%)
Sohag	2	1.72	0.28	14.00
BARI soybean-4	2.2	1.62	0.58	26.36
BARI soybean-5	2	1.63	0.37	18.50
BARI soybean-5	2.1	1.95	0.15	7.14

4.8 Correlation between disease incidence (%) with yield (t/ha) among soybean varieties

The relationship between disease incidence (%) and yield performance of soybean plants also studied. From the study it was revealed that there is inverse relation between disease incidence (%) and yield (t/ha). When the disease incidence (%) increased the yield production reduced. The relation between yield and disease incidences (%) of SMV is shown in **Figure 4**. This figure showed a negative correlation between disease incidence (%) and yield (t/ha). There was a negative and significant relationship (R^2 = 0.531 and Y=3.086-0.723Y) between yield and disease incidence (%).

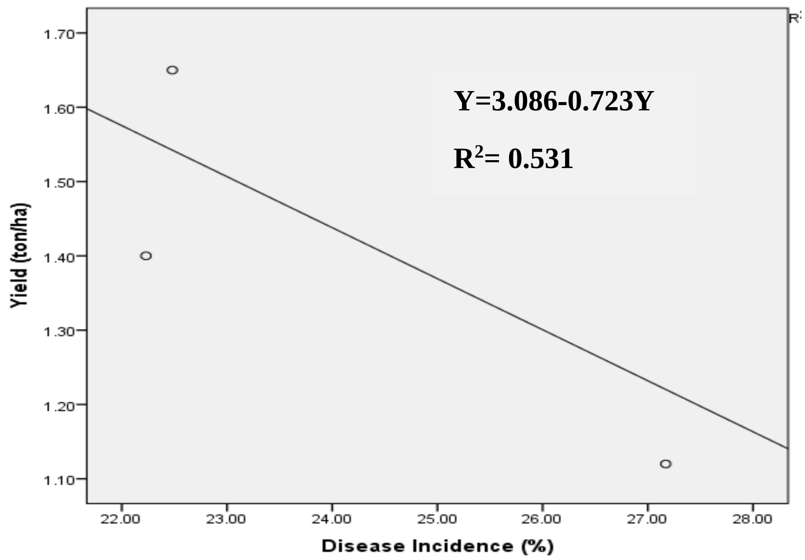


Figure 4. Relationship between disease incidence (%) and yield (t/ha)

4.9 Correlation between disease incidence (%) with yield reduction (%) among soybean varieties

The relationship between disease incidence (%) and yield reduction (%) performance of soybean plants also studied. From the study it was revealed that there is positive relation between disease incidence (%) and yield reduction (%). When the disease incidence (%) increased yield reduction (%) also increased. The relation between yield reduction (%) and disease incidences (%) of SMV is shown in **Figure 5**. This figure showed a positive correlation between disease incidence (%) and yield reduction (%). There was a positive and significant relationship (R^2 =0.284 and Y= -16.573+0.533X) between yield reduction (%) and disease incidence (%).

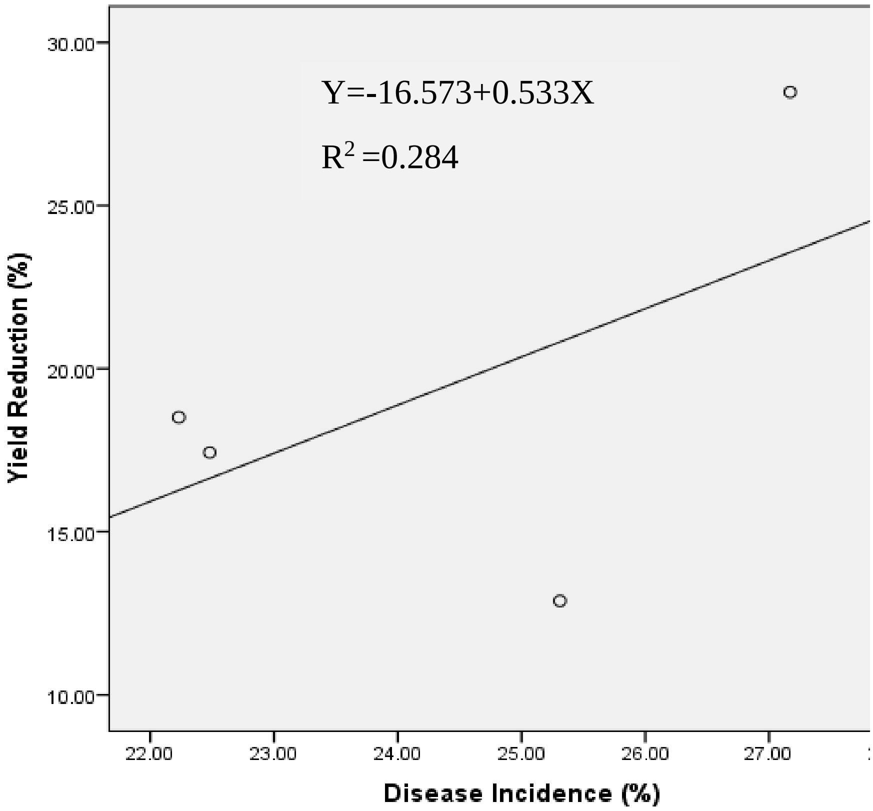


Fig 5. Relationship between disease incidence (%) and yield reduction (%)

Discussion

Soybean is a leguminous crop that is a new potential crop for Bangladesh and the most significant grain legume in the world. It is more appropriately categorized as an oil seed crop than a pulse that is one of the most well-known proteins- and oil-rich crops in the world. The health of soybeans is seriously threatened by two significant groups of organisms: plant pathogenic fungus and viruses. Plant pathogenic fungi can alter seed composition and reduce yield in addition to reducing output. One of the most severe, damaging, and pervasive diseases of *Glycine max* is Soybean mosaic disease (SMD). The experiment was conducted to screen the suitable variety against *Soybean mosaic virus* (SMV).

Significant variations for all the characters on several DAS were revealed in the study. The disease incidence due to *Soybean Mosaic Virus* (SMV) was found in almost all the varieties. The highest disease incidence was found in the Sohag (27.17%) whereas the lowest disease incidence (%) was also found in BARI soybean-4 (22.23%), respectively at 90 DAS. The maximum disease severity (%) was recorded from BARI soybean-5(18.13) and the minimum in BARI Soybean-4(10.65). Among the test varieties, the lowest disease severity (%) was found in the variety BARI Soybean-4. All the varieties except BARI Soybean-5 were previously released as tolerant varieties of *Yellow mosaic diseases* by BARI. In case of disease incidence at an early stage, BARI Soybean-6 (17.78) had the highest incidences whereas disease severity Sohag (8.21) showed the highest value. Later, in the maturity stage, Sohag (27.17) showed the maximum value in the case of disease incidence whereas a little bit change in disease severity. Similar findings were calculated by (Kumar *et al*. 2014) and yield loss caused by SMV typically ranges between 8%-35% and in the severe case may reach up to 100% (Singh and Awasthi 2004).

Bachkar *et al*. 2019 screened twelve varieties of soybean. They 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 resistant and two showed a highly resistant reaction.

In case of the growth attributes, data analysis regarding the plant height of presentation soybean indicated a significant difference on 60 DAS. Mehta and Asati 2008 reported that plant height is an important factor because they have the highest positive effect on yield. In these findings, the plant height (18.98-22.78 cm), (32.13-36.04cm) and (41.31-41.97) cm at 60 DAS, 75 DAS and 90 DAS. In considering the parameters, BARI Soybean-4 performed better at maturity level against *Soybean Mosaic Virus*.

In the case of the number of branches plant^{-1}, up to 90 DAS of different soybean varieties**.** The number of branches is directly related to producing more leaves that are also correlated to producing the number of yields (Tasisa *et al*. 2012). In the case of leave number, the number of leaves at 90 DAS of different Soybean varieties**.** A study on growth and growth contributing characteristics in the hilly area done by (Shaheenuzzamn *et al.* 2014) showed a reduction of growth characteristics in soybean varieties due to soybean mosaic disease.

In the case of yield and yield attributing traits, the maximum pod number was recorded in BARI Soybean-4 (43.20) and the minimum pod number was recorded in BARI Soybean-4 (25.40). The maximum number of seeds/pod was recorded in BARI Soybean-5 (2.55) and the minimum number of seeds/pod was recorded in Sohag (2.16). A maximum 100 seed weight was recorded in Shohag (13.44) and a minimum 100 seed weight was recorded in BARI Soybean-4 (5.63). The highest yield recorded in BARI Soybean-6 (1.61 t/ha) was preceded by BARI Soybean-4 (1.32 t/ha). (Cho and Goodman, 1979; Seo *et al*., 2009; Shrirao *et al*., 2009 and Steinlage et al., 2002) reported that in particular, presentation soybean by SMV, plants may result in yield losses because of the noticeable reduction in the number of seeds produced by *Soybean Mosaic Virus*-presentation plants.

Due to *Soybean Mosaic Virus* infection, the highest yield reduction was calculated for Sohag (28.48%) On the other hand BARI Soybean-5 (12.88%) had the lowest yield reduction. In the case of BARI Soybean-4, the minimum yield loss (24.14%) was recorded in comparison to the expected yield whereas maximum yield loss was found in Sohag (28.50%). There was a negative in incidence and yield and positive relation between incidence and yield reduction (Prinky, 2016).

CHAPTER V

SUMMARY AND CONCLUSION

The prime aim of the present piece of research work was to screen out the resistant varieties of soybean against *Soybean Mosaic Virus* (SMV) which is transmitted by aphids. Four soybean varieties Sohag, BARI Soybean-4, BARI Soybean-5, and BARI Soybean-6 were evaluated in the experiment. Among them, no variety was previously released as a resistant variety against (SMV). The experiment was laid out in Complete Randomized Design (CRD) with three replications.

The soybean varieties differed significantly among themselves in respect of disease incidence at 90 DAS. The highest disease incidence (%) was recorded from Sohag (27.17%) which was significantly different from the varieties BARI soybean-4 (22.23%) and BARI soybean-6 (22.48%) followed by the variety BARI soybean-5 (25.31%) whereas the lowest disease incidence (%) was also found from BARI soybean-4 (22.23%).

In the case of disease severity (%), at 90 DAS, Significant variation was found among the varieties. The maximum disease severity (%) was recorded from BARI soybean-5 (18.13%) which is significantly different from all the varieties BARI soybean-6 (14.29%) and Sohag (12.79) was followed by the variety BARI soybean-4 (10.65%).

At 90 DAS, Sohag showed the maximum value in the case of disease incidence whereas a little bit change in disease severity. At 90 DAS. BARI Soybean-5 disease severity (%) showed the maximum value.

At the early stage of growth up to 60 DAS, the growth of plants of the tested four varieties was slow. At this stage, among the four varieties, BARI soybean-6 showed significantly the highest plant height (22.78 cm) which was significantly different from the other varieties while BARI soybean-4 showed the lowest height (18.98 cm). The rate of increase in plant height was higher from 60 DAS to 75 DAS, after that the values of plant height increased the same as before up to 90 DAS and the highest plant height was attained at this stage for all four varieties.

In case of a number of branches, the maximum values of number of branches plant^{-1} were recorded from BARI soybean-5 (13.11) followed by the varieties BARI soybean-6 (11.50), and BARI soybean-4 (9.98) while Sohag (9.79) consisting the minimum number of branches plant^{-1}.

In the case of number of leaves at 90 DAS, Significant variation was found among the varieties at $p < 0.01$. The maximum number of leaves plant^{-1} was recorded from BARI soybean-4 (26.07) which is significantly different from the varieties Shohag (22.17) and BARI soybean-6 (21.24) followed by the variety BARI soybean-5 (24.80)

In the case of yield and yield contributing traits, maximum pod number was recorded in BARI Soybean-4 (43.20) which was significantly different from the variety BARI Soybean-5 (35.22) and identically similar to the varieties BARI Soybean-6 (32.0) as well as Sohag (31.73) while the minimum number of pods plant^{-1} was recorded in BARI Soybean-5 (25.40), statistically similar with other varieties except for BARI Soybean-4 (43.20).

Maximum pod length (cm) was recorded in BARI Soybean-6 (3.38 cm) which was significantly different from the variety Sohag (3.12 cm) and identically similar to the varieties BARI Soybean-4 (3.21 cm) as well as BARI Soybean-5 (3.37 cm) while the minimum pod length (cm) was recorded in Suhag (3.12 cm), statistically similar with BARI Soybean-4 (3.21 cm).

The maximum number of seed pod^{-1} was recorded in BARI Soybean-5 (2.55) which was followed by the variety BARI Soybean-6 (2.55), and BARI Soybean-4 (2.45), where they were statistically similar and significantly different from the variety Sohag (2.16). The minimum number of seed pod^{-1} was also found in Sohag (2.16)

On the hand, maximum 100 seed weight was recorded in Sohag (12.24 g) followed by the varieties BARI Soybean-5 (11.32 g) and BARI Soybean-6 (10.75 g) where they were statistically similar and significantly different from the variety BARI Soybean-4 (5.63 g). The minimum seed weight was also recorded in BARI Soybean-4 (5.63 g).

The maximum yield (t/ha) was recorded in BARI Soybean-6 (1.61 t/ha) which was followed by the variety BARI Soybean-5 (1.42 t/ha), and BARI Soybean-4

(1.32 t/ha), where they were statistically similar and significantly different from the variety Sohag (1.23 t/ha). The minimum yield (t/ha) was also found in Sohag (1.23 t/ha)**.**

Due to *Soybean Mosaic Virus* infection, the highest yield reduction was calculated for Sohag (28.48%) On the other hand BARI Soybean-5 (12.88%) had the lowest yield reduction.

In the case of BARI Soybean-4, the minimum yield loss (24.14%) was recorded in comparison to the expected yield whereas maximum yield loss was found in Sohag (28.50%).

Considering the above things, the following conclusion may be done-

- ✓ Among selected varieties, BARI soybean-4 (22.23%) performed lowest incidence compared to other varieties whereas Sohag (27.17%) showed highest incidence and severity followed by BARI soybean-6 (14.29%) and BARI soybean-5 (18.13%) whereas the lower disease incidence (%) was also found in BARI soybean-4 (10.65%) respectively.
- ✓ In case of growth characteristics like plant height, the number of branches per plant comprising the number of leaves BARI Soybean-4 was dominant variety over others where the maximum number of leaves plant^{-1} was recorded from BARI soybean-4 (26.07)
- ✓ In the case of yield and yield attributing traits, Maximum pod number was recorded in BARI Soybean-4 (43.20), maximum pod length was recorded in BARI Soybean-6 (3.38 cm), and the maximum number of seed pod^{-1} was recorded in BARI Soybean-5 (2.55) which was followed by the variety BARI Soybean-6 (2.54). The Maximum 100 seed weight was recorded in Sohag (12.24 g).
- ✓ The highest yield reduction was found in Sohag (28.48%) on the other hand BARI Soybean-5 (12.88%) had the lowest yield reduction. There was a negative in incidence and yield and positive relation between incidence and yield reduction.

So, the performance of the variety BARI-4 was much better than the other varieties against *Soybean mosaic virus* (SMV) in field whereas Sohag showed worse performance against SMV over other varieties in all traits.

RECOMMENDATIONS

Considering the performance of the soybean varieties against *Soybean Mosaic Virus* may be recommended that

- From field screening, BARI Soybean-4 was graded as resistant compared to bother selected variety The rest of the varieties were moderate resistant. As the experiment was conducted in Rabi season,
- Further research need to be done in different locations as well as different varieties. Also need to carry out for consecutive seasons as well as in different agro ecological zones of the country to justify the present findings.

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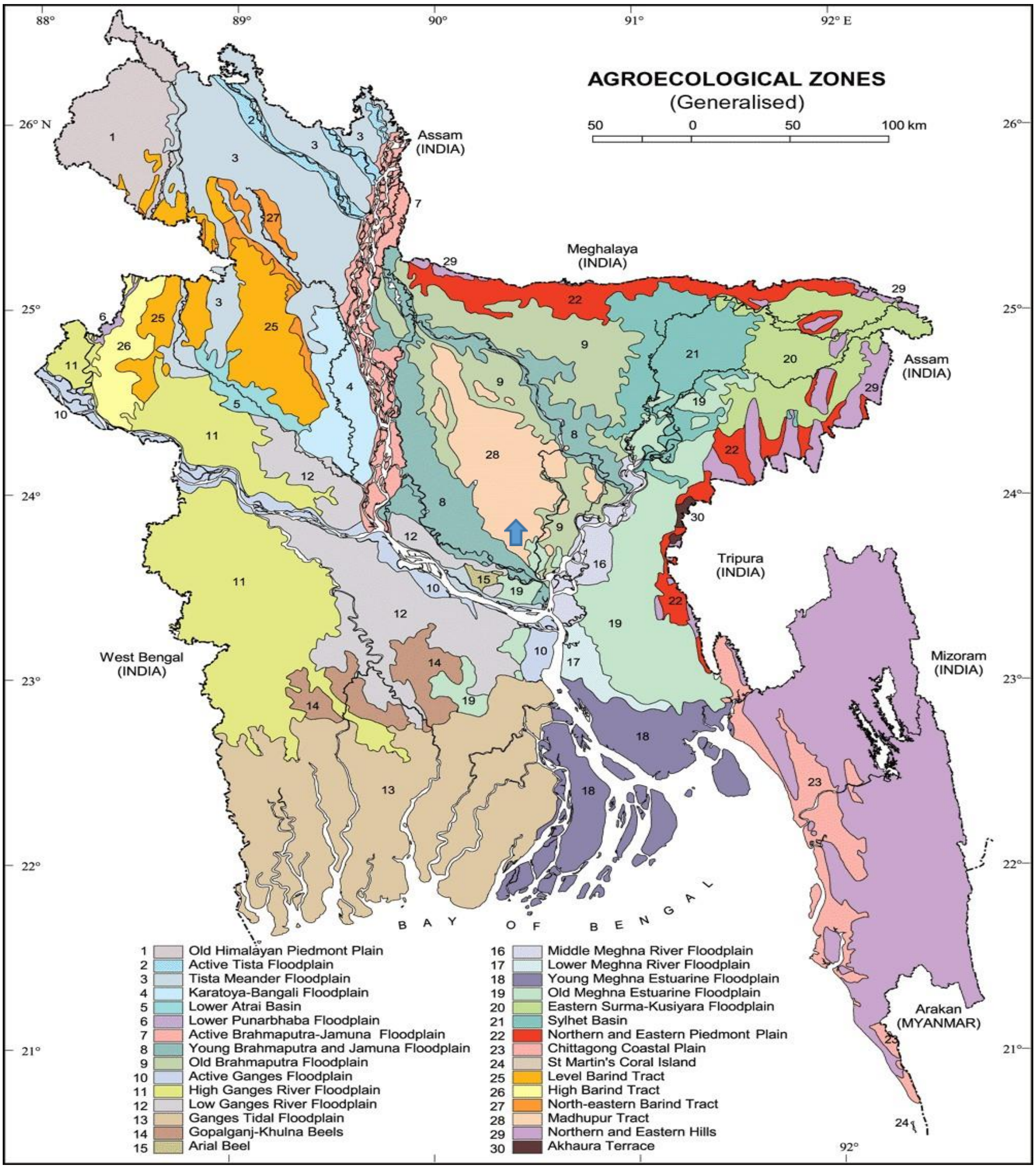
APPENDICES

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



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

Morphological characteristics

Morphological features	
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

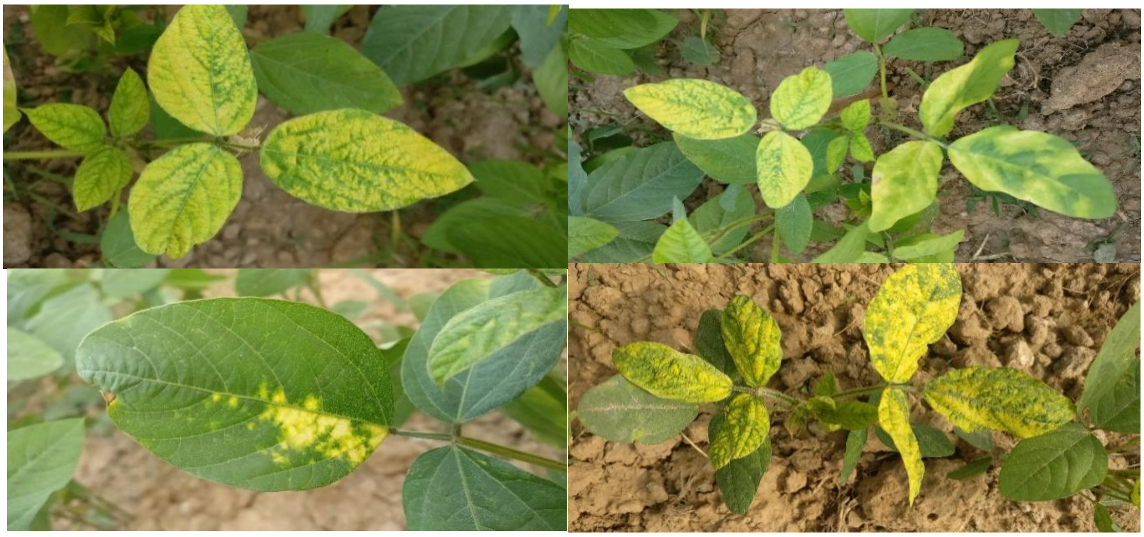
Appendix III: Monthly meteorological information during the period from November, 2020 to April, 2021

Year	Month	Temperature (^{0} C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2020	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	00
2021	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 field during cultivation in experimental field

(A) Experimental field **(B) Experimental plots**



(C) Diseased leaf

(D) Data collection **(E) Healthy Pod**