# ECO-FRIENDLY MANAGEMENT OF *Mungbean Yellow Mosaic Virus* (*MYMV*) THROUGH BARRIER CROPS AND COLORED PLASTIC MULCHES

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# *CERTIFICATE*

*This is to certify that the thesis entitled, "* ***ECO-FRIENDLY MANAGEMENT OF Mungbean Yellow Mosaic Virus (MYMV) THROUGH BARRIER CROPS AND COLORED PLASTIC MULCHES"*** *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 result of a piece of bona-fide research work carried out by* ***WARINA WASEK, REGISTRATION NO. 15-06718*** *under my supervision and guidance. No part of the 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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***Dedicated to***

***My***

***Beloved Parents***

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**ECO-FRIENDLY MANAGEMENT OF *Mungbean Yellow Mosaic Virus* (*MYMV*) THROUGH BARRIER CROPS AND COLORED PLASTIC MULCHES**

## ABSTRACT

Mungbean (*Vigna radiata* L.) is an excellent and easily digestible dietary source of plant protein. Mungbean yellow mosaic disease caused by *Mungbean yellow mosaic virus (MYMV)* which is transmitted by whitefly (*Bemisia tabaci*), an important constraint of mungbean cultivation. A field experiment was conducted at the central farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during March to June, 2021. The prime aim of the study was to manage the *Mungbean yellow mosaic virus (MYMV)* by controlling the insect vectors using barrier crops (sesame, linseed, maize, coriander) and colored plastic mulches (red, blue, silvery-grey, black). BINA released variety BINAmoog-5 was used as a planting material in the experiment. Morphological and physiological parameters were all considerably impacted in this study. Disease incidence and percent disease index of *MYMV* was significantly varied among the treatments. The lowest disease incidence (5.35%, 8.95%, 17.91% per plot and 5.24%, 11.75%, 19.09% per plant at 30, 45 and 60 DAS, respectively) was estimated when maize was used as a barrier crop while the highest disease incidence (25.92%, 35.52%, 61.10% per plot and 27.66%, 34.15%, 59.72% per plant at 30, 45 and 60 DAS, respectively) was found in control treatment. In case of colored plastic mulches, the lowest disease incidence (8.56%, 14.35%, 23.91% per plot and 8.23%, 15.76% 24.70% per plant at 30, 45 and 60 DAS, respectively) was recorded when silvery-grey colored plastic mulch was used. The lowest percent disease index (5.55%, 13.39% and 20.16% at 30, 45 and 60 DAS, respectively) was also found when maize was used as a barrier crop. In case of colored plastic mulches the lowest percent disease index (7.42%, 17.97% and 26.70% at 30, 45 and 60 DAS, respectively) was computed when silvery-grey colored plastic mulch was used. Again, the highest percent disease index (28.14%, 37.71% and 64.08% at 30, 45 and 60 DAS, respectively) was found in control treatment. The highest chlorophyll content, number of flower, pod and yield was measured and counted when maize was used as a barrier crop and silvery-grey colored mulch was used as a colored plastic mulch. However, maize or silvery-grey colored plastic mulch uniquely or combindly can be used to control whitefly (vector) for the management of *MYMV*.

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| µg | Microgram |
| µl | Micro Litre |
| AEZ | Agro-Ecological Zone |
| BARI | Bangladesh Agricultural Research Institute |
| BINA | Bangladesh Institute of Nuclear Agriculture |
| BBS | Bangladesh Bureau of Statistics |
| BSMRAU | Bangladesh Sheikh Mujibur Rahman Agricultural University |
| CV% | Percent Coefficient of Variation |
| DAS | Day after sowing |
| DI | Disease incidence |
| *et al.*, | All others |
| etc. | Etcetera |
| FAO | Food and Agricultural Organization |
| g | Gram |
| LSD | Least significant differences |
| mm | Millimeter |
| MoP | Muriate of potash |
| *MYMV* | *Mungbean Yellow Mosaic Virus* |
| ppm | Parts per million |
| PDI | Percent disease index |
| SAU | Sher-e-Bangla Agricultural University |
| RCBD | Randomized complete block design |
| SRDI | Soil Research and Development Institute |
| TSP | Triple super phosphate |

# CHAPTER I

# INTRODUCTION

Mungbean (*Vigna radiata* L. Wilczek) popularly known as green gram, believed to be native crop of India, is a tiny circular shaped bean in green color. The mung bean (*Vigna radiata* L.) is one of the most important edible legume crops, grown on more than 6 million ha worldwide (about 8.5% of the global pulse area) and consumed by most households in Asia. Due to its characteristics of relatively drought-tolerant, low-input crop, and short growth cycle (70 days or so), the mung bean is widely cultivated in many Asian countries (concentrated mainly in China, India, Bangladesh, Pakistan, and some Southeast Asian countries) as well as in dry regions of southern Europe and warmer parts of Canada and the United States (Dahiya *et al.* 2015). Mungbean belongs to family fabaceae, is a legume cultivated for its edible seeds and sprouts. However, legume seeds constitute an essential part of the human diet as they are excellent sources of proteins, bioactive compounds, minerals, and vitamins, in comparison with cereals, and are referred to as "the poor man's meat" (Hall *et al.*, 2017; Singh *et al.*, 2017). For those individuals who can not afford animal proteins or those who are vegetarian, the mung bean is of a comparatively low-cost and has a good source of protein for them. Furthermore, mung bean protein is easily digestible, as compared to protein in other legumes (Mubarak, A.E. 2005; Yi-Shen *et al.* 2018). Mungbean contains appreciable quantity of lysine, and can therefore be used to complement cereals (Onwurafor *et al.*, 2014). Consumption of the mung bean combined with cereals has been recommended to significantly increase the quality of protein, because cereals are rich in sulfur-containing amino acids but deficient in lysine (Boye *et al.*, 2010). The mung bean is a fast-growing, warm-season legume. The agro-ecological condition of Bangladesh is favorable for growing this crop. The optimum temperature ranges from 20°- 35°C depending upon season (BARC, 2013). It can be sown during summer and autumn. It does not require large amounts of water (600-1000 mm rainfall/year) and is tolerant of drought. It is sensitive to waterlogging. High moisture at maturity tends to spoil the seeds that may sprout before being harvested. The mung bean grows on a wide range of soils but prefers well-drained loams or sandy loams, with a pH ranging from 5 to 8. It is somewhat tolerant to saline soils. Mungbean is considered as the best of all pulses from the nutritional point of view which contains vitamin A (94 mg), iron (7.3 mg), calcium (124 mg), zinc (3 mg) and folate (549 mg) per 100 g dry seed. It has carbohydrate (51 %), protein (24-26 %), mineral (4 %), vitamins (3 %) and fat (1 %) (Afzal *et al*., 2008). The mature seeds provide an invaluable source of digestible protein for humans in places where meat is lacking or where people are mostly vegetarian (AVRDC, 2012). Along with the nutritional factors, pulses also contain flatulence causing raffinose family oligosaccharides, phytate, heat-stable and heat-labile anti-nutritional and toxic factors (Salunkhe, 1982). Mung bean induces less flatulence and is well tolerated by children (Kumar *et al*. 2014). In many studies, the mung bean was recommended as a supplement for preparing an infant's weaning food because of its high protein content and hypoallergic properties (Bazaz *et al*. 2016, Ali *et al*. 2016). Mung beans are cooked fresh or dry. They can be eaten whole or made into flour, soups, porridge, snacks, bread, noodles and ice-cream. Split seeds can be transformed into dhal in the same way as black gram or lentils. Mung beans can be processed to make starch noodles (vermicelli, bean thread noodles, cellophane noodles) or soap. The sprouted seeds ("bean sprouts" in English, and incorrectly called "germes de soja" or "pousses de soja" in French) are relished raw or cooked throughout the world. The immature pods and young leaves are eaten as a vegetable. It is grown in three seasons in a year in Bangladesh and more than 70% mungbean area is concentrated in the three southern districts *viz*. Patuakhali, Barisal, and Noakhali within AEZ 13 and 18 and Patuakhali alone occupies about 30% area (Mondol *et al*., 2013). Mungbean is usually sown in this region at the end of January to mid -February. Most of the soils in this region are cracking clay type which becomes compact and hard on drying. Mungbean is grown on an area of land that is approximately 2.308 lakh hectares, producing about 1.28 lakh metric tons of grain in the winter and an area of approximately 0.337 lakh hectares, producing about 0.41 lakh metric tons of grain in the summer (Krishi dairy, 2021). It is suitable for many different cropping systems and provides more than six million hectares of land annually, which is a significant portion of the world's cereal-based diets. However, 90% of the world's mungbean crop is produced only in Asia. India is the greatest mungbean grower in the world, accounting for around 65% of worldwide acreage and 54% of its production.

There are many constrain responsible for the low yield of mungbean. The poor yield is largely due to varietal aspect, climatic factors, management practices, insect pests and diseases (Rahman *et al.*, 1981).

There are 64 species of insect’s attack mungbean (Lal, 1985) from seedling to harvest and budding is the most preferred and attractive stage to insects but a total of 16 species have been reported to attack mungbean in Bangladesh. Of these insect’s pests, white fly, stem fly, hairy caterpillar, and pod borer are the most damaging (Gowda and Kaul, 1982; Rahman *et al*., 1981).

The main reason for the low yield is the susceptibility of the crop to insects, weeds and diseases caused by pathogenic organisms like fungus, virus or bacteria. Among the three, the viruses are the most important group of plant pathogens affecting the production of the crop. They cause severe diseases and economic losses in mungbean by plummeting seed yield and quality (Kang *et al*. 2005). Foot and root rot (*Fusarium oxysporum*, *Sclerotium rolfsii*), Cercospora leaf spot (*Cercospora crunta*), and *Mungbean Yellow Mosaic Virus* (*MYMV*) are the diseases that cause the most crop damage, according to Faruq and Islam (2010). The following biological stressors on mungbean are significant:

*Mungbean yellow mosaic virus, Leaf crinkle virus*, anthracnose, powdery mildew, Cercospora leaf spot, gram pod borer, bruchid, and whitefly (Pande *et al.*, 2000). Plant viral diseases cause serious economic losses in many major crops by reducing seed yield and quality (Kang *et al.*, 2005). Mungbean Yellow Mosaic Disease (MYMD) is reported to be the most destructive viral disease among the various viral diseases, caused by yellow mosaic virus. Among the various diseases, the MYMD was given special attention because of severity and ability to cause yield loss up to 85%, which is spreading faster towards newer areas (AVRDC, 1998). Winter mungbean genotypes are highly susceptible to *MYMV* and caused 67-100% yield (Jalaluddin and Shaikh, 1981). *MYMV* belongs to the family Geminiviridae. It is transmitted by whitefly (*Bemisia tabaci* Genn.). The whitefly is one of the most economically important pests in many tropical and subtropical regions (Karthikeyan *et al.*, 2014). It is found to spread the begomoviruses, the major hazard to the flourishing production of mungbean in Bangladesh, India, Sri Lanka, Pakistan, Papu New Guinea, Philippines and Thailand (Honda *et al*. 1983; Chenulu & Verma 1988; Varma *et al.*1992; Jones 2003; Haq *et al*. 2011). Based on sequence identity analyses, the bipartite begomovirus isolates, namely, *Mungbean Yellow Mosaic Virus* (*MYMV*), *Mungbean Yellow Mosaic India Virus* (*MYMIV*) and *Horse Gram Yellow Mosaic Virus* (*HgYMV*) are recognized as the causal agents of MYMD in different regions of the world (Qazi *et al.* 2007; Malathi & John 2008; Ilyas *et al*. 2010). The most obvious symptom on the leaf starts as little yellow spots along the veinlets and extends to cover the lamina; the pods shrink up and curl upward. A thorough examination of historical records revealed that the disease manifests itself to varying degrees in each of the Asian regions that produce mungbeans. Numerous disease management techniques have been created or put into use for the *MYMV* disease, however none of the commercially marketed mungbean cultivars currently available have been completely resistant to it. The disease continues to represent a serious threat to this crop's economic productivity in the Asian subcontinent.

The development and introduction of enhanced high yielding mungbean cultivars must take a back seat to *MYMV* control for the cultivation of mungbeans to be successful. In Bangladesh, high and somewhat stable resistant mungbean cultivars against *MYMV* infections are still not readily accessible. The Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Institute of Nuclear Agriculture (BINA) have published certain resistant and tolerant cultivars that are dependent on cultural and environmental conditions to remain healthy. There are few reports on *MYMV* management. Controlling insect vectors is a crucial strategy for combating the mungbean yellow mosaic disease. Yellow mosaic disease incidence has been discovered to be decreased by a few chemicals (Borah, 2012). Although the improper use of these chemicals pollutes the environment and poses health risks, other alternatives, such as the use of plant extracts and cultural practices alone, are ineffective against the vector. This serious issue can be resolved with the use of an integrated disease management system and the creation of *MVMY* resistance varieties. It is necessary to correctly identify the virus in order to establish the management plan and resistant variety.

## Objectives:

- To evaluate the potentiality of barrier crops and colored plastic mulches to control insect vector, whitefly (*Bemisia tabaci*)
- To manage the *Mungbean Yellow Mosaic Virus* (*MYMV*) using barrier crops and colored plastic mulches.

# CHAPTER II

# REVIEW OF LITERATURE

Mungbean (*Vigna radiata L. Wilczek*) popularly known as green gram, is a tiny circular shaped bean in green color widely cultivated throughout Asia, including India, Pakistan, Bangladesh, Sri Lanka, Thailand, Laos, Cambodia, Vietnam, Indonesia, Malaysia, South China, and Republic of Formosa. This short-term legume can grow in varying environmental conditions, and later it expands it reach to the USA, Australia, and Africa. In general, mung bean is a source of high-quality protein which can be consumed as whole grains, dhal, or sprouted form and is an excellent complement to rice in respect to balanced human nutrition. In addition to being the prime source of human food and animal feed, it plays an important role in maintaining the soil fertility by enhancing the soil physical properties and fixing atmospheric nitrogen. Due to this crop's huge importance numerous studies on mungbean production have been conducted in South East Asian nations, particularly in the Indian subcontinent for the increase in quality and yield. Researchers in Bangladesh began studying mungbeans in the early 1980's with a focus on improving this short-duration pulse crop to meet the demand for protein. Both the Bangladesh Institute of Nuclear Agriculture (BINA) and the Bangladesh Agricultural Research Institute (BARI) introduced their first mungbean varieties, BARI mung-1 and BINAmoog-1, respectively, in 1982 and 1992. 17 mungbean cultivars have previously been made public by these two renowned research institutions. The Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) recently began study on this crop's enhancement and varietal development. There are several diseases that affect mungbean (*Vigna radiata L. Wilczek*), and the yellow mosaic disease particularly harms this crop severely. This chapter reviews and discusses the results of several experiments conducted both domestically and internationally.

## 2.1. Morphology of mungbean

The mung bean (*Vigna radiata* (L.) R. Wilczek) is a legume cultivated for its edible seeds and sprouts across Asia. There are 3 subgroups of *Vigna radiata*: one is cultivated (*Vigna radiata* subsp. *radiata*), and two are wild (*Vigna radiata* subsp. *sublobata* and *Vigna radiata* subsp. *glabra*).

The mung bean plant is an annual, erect or semi-erect, reaching a height of 0.15-1.25 m (FAO, 2012; Lambrides *et al*., 2006). It is slightly hairy with a well-developed root system. Wild types tend to be prostrate while cultivated types are more erect (Lambrides *et al*., 2006). The stems are many-branched, sometimes twining at the tips. The leaves are alternate, trifoliolate with elliptical to ovate leaflets, 5-18 cm long x 3-15 cm broad. The flowers (4-30) are papillonaceous, pale yellow or greenish in colour. The pods are long, cylindrical, hairy and pending. They contain 7 to 20 small, ellipsoid or cube-shaped seeds. The seeds are variable in colour: they are usually green, but can also be yellow, olive, brown, purplish brown or black, mottled and/or ridged. Seed colours and presence or absence of a rough layer are used to distinguish different types of mung bean (Lambrides *et al*., 2006).

Cultivated types are generally green or golden and can be shiny or dull depending on the presence of a texture layer (Lambrides *et al*., 2006). Golden gram, which has yellow seeds, low seed yield and pods that shatter at maturity, is often grown for forage or green manure. Green gram has bright green seeds, is more prolific and ripens more uniformly, with a lower tendency for pods to shatter. In India, two other types of mung beans exist, one with black seeds and one with brown seeds. The mung bean resembles the black gram (*Vigna mungo* (L.)) with two main differences: the corolla of *Vigna mungo* is bright yellow while that of *Vigna radiata* is pale yellow; mung bean pods are pendulous whereas they are erect in black gram. Mung bean is slightly less hairy than black gram. Mung bean is sown on lighter soils than black gram.

## 2.2. Plant Virus

The word “virus” (from the Latin nounvirus, which means “slimy liquid” or “poison”) has been used since the late 14th century to refer to poisonous substances. In 1892, Ivanovsky demonstrated that the sap of a diseased tobacco plant remained infectious even after passage through Pasteur-Chamberland filters (pore size typically 0.2mm) that were used to hold back cellular organisms, such as bacteria (Iwanowsky D. 1892). Shortly thereafter, similar observations were made and also reported that filtered diluted tobacco plant sap remained as infectious as undiluted sap which was referred as a contagium vivum fluidum (a contagious living liquid). Subsequently, infectious agents that could pass through Pasteur-Chamberland filters were referred to as “ultra (filterable) viruses,” and the agent causing tobacco mosaic disease was hence called *Tobacco Mosaic Virus* (*TMV*) (Scholthof KB. 2004). With the increasing recognition that some agents specifically infected particular cellular organisms, the term “virus” was adopted exclusively for non-organismal / non-cellular filterable agents.

Viruses are the most genetically diverse organisms that cause infections in plants, animals, and humans. In general, viruses consist of a small genome that encodes only a few proteins, which makes it difficult to control viruses with a variety of methods (Rojas, 2008)

In plants, among all the disease-causing pathogens, viruses present the substantial risk for agricultural production and have been reported to cause around half of the emergent infectious diseases among a variety of crop plants that cause about 40% of total crop losses upon viral infection (Maksimov, 2019)

Therefore, viruses represent one of the major constraints in agricultural production worldwide by decreasing both the quality and quantity of food crops (Hanˇcinský, 2020)

Globally, more than twenty-five families of plant viruses are known to infect a variety of crop species, leading to higher economic losses (He, 2020).

Plant viral species are predominantly transmitted and spread by vertical and horizontal modes of transmission. In the vertical mode, the passage of the infectious agent occurs through the parent plants, either through vegetative propagation or by sexual reproduction via infected seeds. In the horizontal mode, spreading typically occurs through insect vectors, agricultural tools, as well as other direct or external forms of contamination (Gallet, 2018).

Upon infection by a viral species, various symptoms, such as mosaic damage, yellowing, chlorosis, stunting, and necrosis are observed in infected plants, leading to loss of proper growth and reproductive functions of the plants (Seo, 2018).

### 2.3. Viral Diseases on Different Crops

Plant virus affects systemically and this infection causes severe disease symptoms, the magnitude of the resulting losses in overall crop yield or quality of produce can be devastating. Moreover, such losses happen in both annual and perennial cultivated plants.

Oswald (1953) first reported that in 1951 in California, USA Yellow dwarf disease (YDD) causes the virus disease epidemic of greatest global significance for wheat.

Singh, K. (2018) reported in 1922 in USA Wheat streak mosaic disease (WSMD) causes the second most important virus disease of wheat globally.

Rice tungro disease (RTD) constitutes the most devastating virus disease of rice in tropical regions of Southeast Asia, southern China and the Indian subcontinent, where it causes a devastating pandemic, reported by Thresh 1980, 2006; Rybicki 1999; Bunawan 2014.

Potato crops suffer from many virus diseases (Jones, 2014; Kreuze, 2020; Stevenson, 2001).

PVY's role in causing potato disease covering the period starting when the virus was first found up until its recent re-emergence as the cause of the current major global potato disease epidemic caused by its necrogenic R2 variants. These variants, which cause potato tuber necrotic ringspot disease (PTNRD; Figure 2A), arose by recombination between two of its strains (Karasev, 2013; Jones, 2014; Kreuze, 2020; Gray, 2010; Gibbs, 2017; Torrance, 2020)

Sweet potato virus disease (SPVD) causes the most devastating virus disease of the sweet potato crop. It is caused by mixed infection with the sweet potato chlorotic stunt virus (SPCSV; genus, Crinivirus, family, Closteroviridae) and a member of the Potyviridae family. The latter virus is usually *Sweet Potato Feathery Mottle Virus* (*SPFMV*; genus, Potyvirus family, Potyviridae) or *Sweet Potato Mild Mottle Virus* (*SPMMV*; genus, Ipomovirus, family, Potyviridae). A synergistic interaction between *SPCSV* and *SPFMV* or *SPMMV* causes a very damaging disease consisting of severe leaf mosaic and malformation and plant stunting, and a tuberous root yield reduction of >85% reported by Tairo, 2005 and Gibson, 1998.

Banana bunchy top disease (BBTD) causes a devastating pandemic in banana crops. It constitutes the most damaging virus disease affecting this crop on a global scale and seriously threatens food security in developing countries (Kumar, 2011; Kumar, 2015; Dale, 1987).

Citrus tristeza disease was first recorded in the 1930s in Argentina and shortly afterwards in Brazil and several other South American countries. Virtually all citrus trees growing on sour orange rootstocks were killed and plantations abandoned in worst-affected regions. By 1959 in Brazil's Sao Paulo state, 75% of all orange trees (i.e., 6 million trees) were killed, and similar problems occurred in South Africa, West Africa and California reported by Thresh, 1980.

Faba bean necrotic yellows disease (FBNYD) epidemics cause severe yield losses and crop failure in faba bean crops. FBNYD was reported first in Syria in 1986 Observed by Makkouk, 1988.

Salem, 2016 reported that *Tomato Brown Rugose Fruit Virus* (*ToBRFV*; genus, Tobamovirus, family, Virgaviridae) was first found in 2014 infecting tomato in Jordan so, apparently, it only emerged recently.

*Cucumber Green Mottle Mosaic Virus* (*CGMMV*; genus Tobamovirus, family, Virgaviridae) was amongst the earliest plant viruses described. This was in 1935 when it was found to cause a cucumber disease in glasshouse crops in England.

## 2.4. Yellow Mosaic Disease on Mungbean and Its Symptoms

In addition of providing a wealth of carbohydrates, the mungbean is an essential, environmentally beneficial food grain crop. It ranks close to cereals in terms of nutritional and economic value. Mungbean is an important and cheap source of food protein across Asia, especially for the poor, thus plays an imperative role in the alleviation of protein malnutrition especially in the developing countries (Selvi *et al.*, 2006). It contains a relatively high proportion of easily digestible good quality protein (24%) with low flatulence and is also rich in iron contents (40–70 ppm), making it an ultimate choice for balanced diets (Selvi *et al.*, 2006; Vairam *et al.*, 2016). Besides seeds, its sprouts, which contain high vitamin C and folate are also very much relished in Asian cuisine (Nair *et al.*, 2013). Globally, mungbean is being grown in over 7.0 million ha area, yielding 3.5 million tons of grains mainly from Asia but spreading to other parts of the world

(Nair *et al*., 2019). The major mungbean growing countries include India, China, Pakistan, Bangladesh, Sri Lanka, Thailand, Myanmar, Vietnam, Indonesia, Australia, and the Philippines (Alam *et al*., 2014).

The main reason for the low yield is the susceptibility of the crop to insects, weeds and diseases caused by fungus, virus or bacteria. Among the three, the viruses are the most important group of plant pathogens affecting the production of the crop. They cause severe diseases and economic losses in mungbean by plummeting seed yield and quality (Kang *et al.* 2005).

In mungbean, yellow mosaic disease (YMD) caused by *Yellow Mosaic Viruses* (*YMV*s) is of key importance especially in South and Southeast Asia. Besides mungbean, YMD also affect various leguminous crops including blackgram (*Vigna mungo*), mothbean (*Vigna aconitifolia*), Lima bean (*P. lunatus*), pigeonpea (*Cajanus cajan*), French bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), Dolichos (*Lablab purpureus*), horsegram (*Macrotyloma uniflorum*), and soybean (*Glycine max*) observed by Ramesh *et al*., 2017; Dikshit *et al.,* 2020.

The overall crop yield loss may range between 10 and 100%, depending on the mungbean genotype and stage of crop infection (Singh, 1980; Marimuthu *et al*., 1981; Bashir *et al.*, 2006).

YMD spread to the mungbean crop through whitefly (*Bemisia tabaci* Gennadius)—an insect vector for *YMV*s (Selvi *et al.,* 2006).

Nene (1969) observed that in case of severe infection only very few number of pods were produced.

Although, YMD has been reported throughout the world (except Australia); but its heavy incidence is mainly reported from countries like India, Bangladesh, and Pakistan (Pathak and Jhamaria, 2004; Biswas *et al*., 2008; Salam *et al.,* 2011).

The virus enters the phloem cells of the host through the whitefly proboscis and the viral aggregates appear in the host cell nuclei roughly two days before the symptom appearance reported by Thongmeearkom *et al.*, 1981.

The visible symptoms appear as scattered yellow-color spots on the young leaves which later turns into a yellow mosaic pattern and ultimately results in complete yellowing, drying and withering of leaves. The pods on the infected mungbean plant become smaller in size, yellowing of the leaves decreases the photosynthetic efficiency which ultimately manifested as severe yield penalty observed by Malathi and John, 2009.

In mungbean first symptom of the disease appears on the young leaves in the form of mild scattered yellow specks or spots. The diseased plants usually mature late and bear a few flowers and pods.

## 2.5. Transmission of Mungbean Yellow Mosaic Disease

A large number of insect pests i.e. aphids, cut worm, foliage caterpillar, jassids, leaf miner, pod borer and whitefly attack mungbean plants. Among these, only whitefly (*Bemisia tabaci*) transmits *MYMV*.

Shad *et al*. (2005) reported that *Mungbean Yellow Mosaic Virus* is not transmitted by mechanical inoculation and seed.

*Bemisia tabaci* is a polyphagus pest being possibly of Indian origin infecting broad host range over 700 plant species including horticultural and agriculturally important crop reported by Fishpool LDC (1994).

*Bemisia tabaci* can transmit 114 virus (Simon B *et al.* 2003) species belong to multiple genera, Begomovirus account 90% and 4% belong to Carlavirus, Crinivirus Closterovirus and Ipomovirus.

Yellow Mosaic Disease is caused by at least four different species of whitefly (*Bemisia tabaci* Genn.)-transmitted-begomoviruses (WTV, family *Geminiviridae*), collectively referred to as *Legume Yellow Mosaic Viruses* (Qazi *et al*., 2007) or "Legumovirus" (Ilyas *et al.*, 2009), and has a very restricted natural host range within legumes. Amongst *LYMV*s, *Mungbean Yellow Mosaic India Virus* (*MYMIV*; Mayo, 2005) and *Mungbean yellow mosaic virus* (*MYMV*; Moringa *et al.*,1993) are most important in black gram.

*Mungbean Yellow Mosaic Virus* has a wide host range and it is transmitted by Whitefly (*Bemisia tabaci* Genn.) and not through seed, sap and soil reported by Nene, 1972.

According to Malathi and John (2008), a single viruliferous adult is capable of transmitting the dreadful virus and it can transmit the virus within an acquisition and inoculation access period of 24 hours. Acquisition and inoculation by whitefly adults can be affected in a minimum of 15 minutes. The insect may attain the virus after a single bite and its transmission efficiency increases with time on the source plant of virus as well as on the healthy mungbean plant.

For 10 and 3 days, respectively, the most effective male and female individuals in a group may maintain their infectiousness. The efficiency of female adults as vectors is therefore three times greater than that of male adults. Adults cannot remain infectious throughout their whole lives, either as females or as males. While the virus does not spread through *Bemisia tabaci* eggs, nymphs of the plant might contract it through damaged leaves.

Yellow Mosaic Disease spread to the mungbean crop through whitefly (*Bemisia tabaci* Gennadius)—an insect vector for *YMV*s reported by Selvi *et al*., (2006).

According to Sekar and Nalini (2017) whiteflies act as vector of *Mungbean Yellow Mosaic Virus* (*MYMV*).

According to Chenulu *et al*., (1979) *MYMV* is transmitted by the whitefly in a circulatory manner. Pre-acquisition and pre-inoculation starvation either increase the efficiency of transmission or have no effect.

*MYMV* disease spread rapidly with increase in the whitefly (Bemisia tabaci) population observed by Aftab *et al.* (1992).

*MYMV* disease severity depends upon the abundance and activities of whitefly population and the time of infection reported by Dhingra and Gosh, 1993.

Nath (I994) observed the relationship between disease incidence and population size of *Bemisia tabaci* in the crop sown. He observed a positive correlation between *MYMV* incidence and population size of *Bemisia tabaci*.

Dantre *et al*., (1996) studied on a yellow mosaic virus disease of soybean and mungbean and reported that the mungbean yellow mosaic Gemini virus was transmitted by whitefly (*Bemisia tabaci*) but not through sap or seed.

## 2.6. Environmental factors that affect vector populations and *MYMV* transmission

The meteorological parameters play significant role in the occurrence and spread of whitefly and significantly affect *MYMV* spread in mungbean during kharif season. Weather conditions mostly influence the population and activity of different insect pests and parasites (Arif *et al*., 2006). *MYMV* disease is the result of a three-way interaction between the host, the pathogen and the environment (Singh *et al*., 2004).

Whitefly population build up maximum from April to October when the average maximum temperature ranged from 21 to 35°C reported by Nene (1972) and Butter (1977).

According to Alam *et al*., (2014) Incidence and management of the *MYMV* disease depend on the vector (whitefly) population, which in turn depends on environmental conditions.

According to Sharma *et al*., (2013), positive correlation between temperature can be attributed to enhanced rate of development and reproduction of whitefly and its ovipositional activity which will be maximum at 33 to $37^0$ C.

According to Sharma *et al*., (2014) Cooler weather and high relative humidity are detrimental to whitefly population because whitefly population occurs when maximum temperature ranged between 34 to $36^0$ c, minimum temperature of 24 to $26^0$ c, relative humidity (morning) of 85 to 90 per cent, relative humidity (evening) of 30 to 40 per cent and sunshine duration of 8 to 8.5 hours.

Marabi *et al*., (2017) reported that the vector survival will be impacted by an increase in relative humidity and gloomy weather during the day.

### 2.7. Host range of *MYMV*

Yellow mosaic disease has a wide range of hosts and is able to infect legumes, including yardlong beans (Nurulita *et al*. 2015), soybean (*Glycine max* L.) (Sutrawati *et al*. 2020), mungbeans and black-eyed pea (*Vigna unguiculata* subsp. *unguiculata*) (Kumar *et al.* 2017).

Yellow mosaic disease infects not only legumes but may also occur on other plant species as inoculum sources in the field. In Indonesia, mixed infections have been reported between *Mungbean yellow mosaic virus* (*MYMV)* with *Tomato yellow leaf curlvirus (TYLCV), Tomato leaf curl virus* (*ToLCV*), and *Pepper yellow leaf curl virus* (*PepYLCV* on yardlong beans (V.U. sesquipedalis) (Sidik *et al*. 2017), mixed infection between *MYMV* with *PepYLCV* have also been reported to infect eggplant (*Solanum melongena* L.), chili pepper

(*Capsicum annuum* L.), melon (*Cucumis melo* L.), and cucumber (*Cucumis sativus* L.) (Purwoko *et al*. 2015).

Yellow mosaic disease has been found to have a wide range of hosts in addition to being seed-borne on mungbeans (*V. radiata*) and to be especially detectable from seed coat, cotyledon, and embryo (Kothandraman *et al*. 2016).

Brown *et al.* (2001) stated that *Bemisia tabaci* populations that are highly associated with viral occurrences can be continuously hosted by mixed or overlapping crops.

**2.8. Effect of Mulch Materials and Barrier Crops on Yellow Mosaic Disease**

In the literature, it has been noted that mulching materials can help plants with illnesses caused by the mosaic virus. Reflective plastic mulch delays and lessens the severity of silver leaf whitefly infestations on cucumber, pumpkin, and zucchini squash reported by Summers and Stapleton, (2002)

Plants planted on reflecting mulch yielded noticeably more marketable fruit than those growing on bare soil (Brown *et al*., 1993).

Mulches also have other benefits, such as changing the temperature and moisture of the soil, which may advance crop maturity and boost crop production while also benefiting the producer more directly and economically.

Mulching has been utilized in crops including sweet potato, potato, tomato, and pepper to produce optimal vegetable growth and output (Awodoyin and Ogunyemi, 2005; Rahman *et al*., 2006).

According to Fereres (2000) For the *Cucumber Mosaic Virus* and *Potato Virus Y*, maize and sorghum are planted in Spain as barrier crops.

According to Schroder and Kruger (2014) In African seed production plots, maize and wheat were utilized as barrier crops to trap populations of aphids carrying potato viruses.

Deol and Rataul (1978) reported that when grown in Punjab as a barrier crop, sunflower, sesame, and pearl millet decreased the prevalence of the *Cucumber Mosaic Virus* in chillies.

# CHAPTER III

# MATERIALS AND METHODS

The present study was carried out in the field condition at central farm of Sher-e-Bangla Agricultural University, Dhaka to manage *Mungbean Yellow Mosaic Virus* (*MYMV*) ecofriendly through barrier cropping and light reflecting mulch. This chapter includes experimental site and duration, planting materials, land preparation, experimental design and layout, crop growing procedure, treatments of the experiment, fertilizer application, management practices, intercultural operations, parameter assessed, data collection, disease incidence, disease severity, chlorophyll content in leaves per plant, Yield along with statistical analysis.

## 3.1. Experimental Site

The experiment was conducted in the central farm of Sher-e-Bangla Agricultural University, Dhaka. The experimental field is located at the 23º74′ N latitude and 90º35′ E longitude with an elevation of 8.2 meter from sea level.

## 3.2. Experimental Duration

The experiment was carried out in Kharif- I season during the period of March to June, 2021. Seeds were sown on 20$^{th}$ March, 2021 and harvested from 29$^{th}$ May to 7$^{th}$ June 2021.

### 3.3. Soil Characteristics

The experiment field's soil has medium high land characteristics and located in Agro Ecological Zone No. 28 of the Modhupur tract. The soil has a silt loam texture, was low in nutrients, non-calcareous, acidic, brown or red in color, and had a pH of 6.7. It belonged to the Tejgaon soil series.

### 3.4. Climate

The experimental location was located in a sub-tropical monsoon climate, which is characterized by abundant rainfall during the kharif season (May to September) and little rainfall during the rabi season (October-March). December, January, and February saw extremely little to no rainfall. Throughout the research period, the average maximum temperature was 32ºC and the average lowest temperature was 20ºC. The Bangladesh Metrological Department in Agargaon, Dhaka, provided information on the metrological statistics in regard to temperature, rainfall, and relative humidity during the experiment.

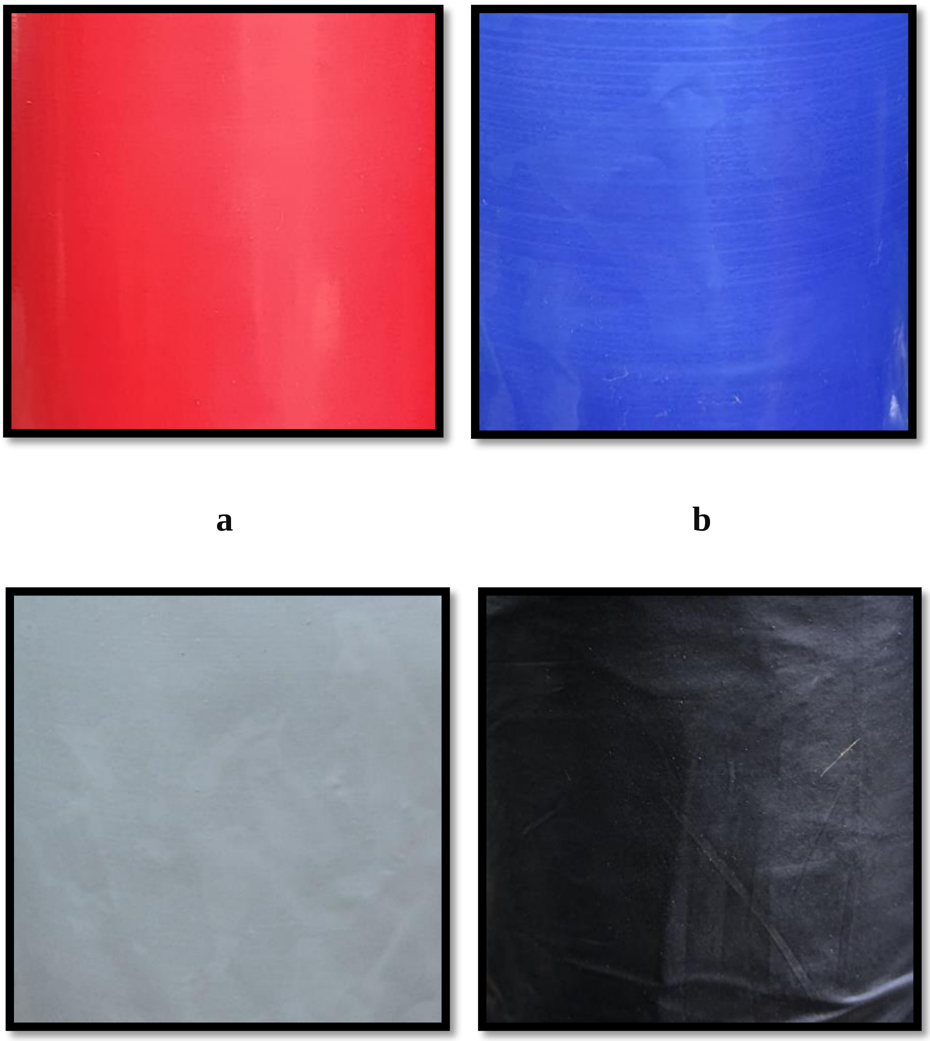
### 3.5. Planting Material

Mungbean variety namely, BINAmoog-5, was used as planting material. Seeds were collected from Bangladesh Institute of Nuclear Agriculrure (BINA), Ishwardi, Pabna.

**Figure 1. Mungbean seed (BINAmoog-5)**

### 3.6. Collection of Colored Plastic Mulches

Colored plastic mulches were collected from Kaptan Bazar, Dhaka.



a b

c d

**Figure 2. Different colored plastic mulches (a. Red, b. Blue, c. Silvery-grey, d. Black)**

### 3.7. Seeds Collection of Barrier Crops

Seeds of barrier crops *viz*.; sesame, linseed, maize and coriander were collected from Siddique Bazar, Dhaka.

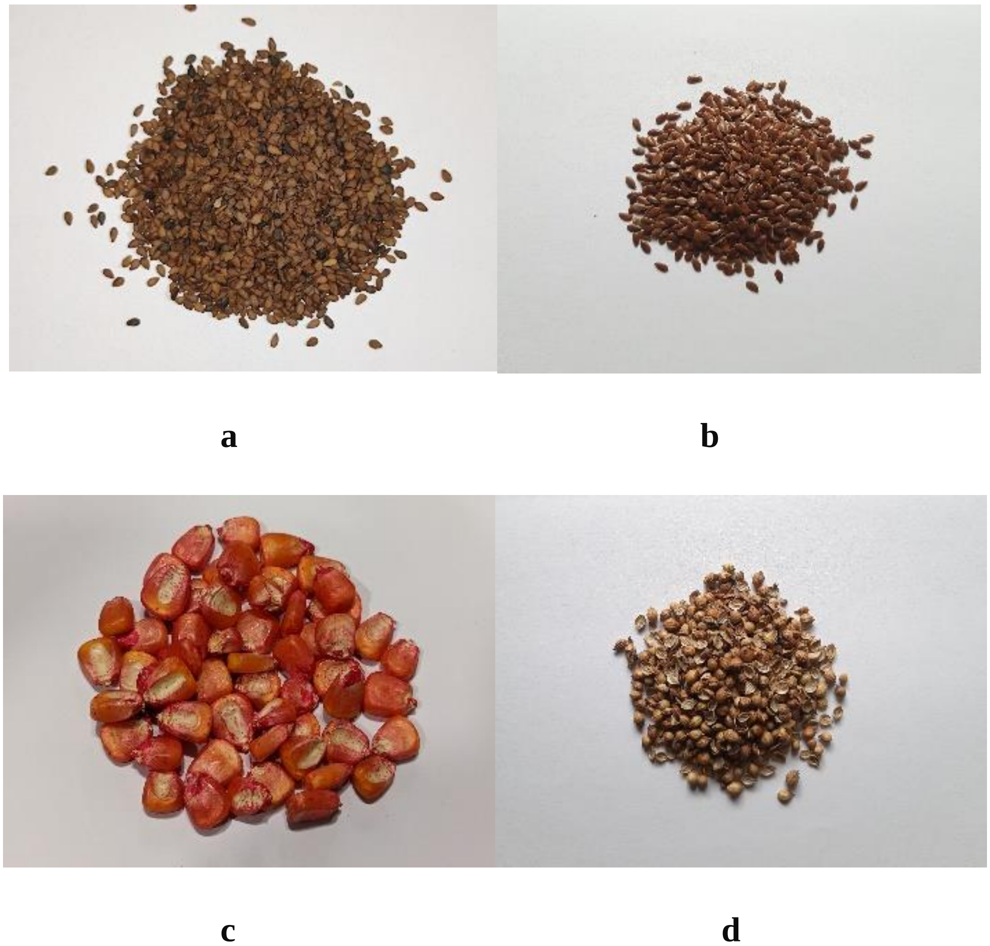



**Figure 3. Seeds of barrier crops (a. Sesame, b. Linseed, c. Maize, d. Coriander)**

### 3.8. Treatments of the experiment

In total nine (9) treatments were confined to conduct the present experiment. The treatments were as follows-

$T_0$= Control

$T_1$= Sesame (Barrier crop)

$T_2$= Linseed (Barrier crop)

$T_3$= Maize (Barrier crop)

$T_4$= Coriander (Barrier crop)

$T_5$= Red colored Polythene (Mulch)

$T_6$= Blue colored Polythene (Mulch)

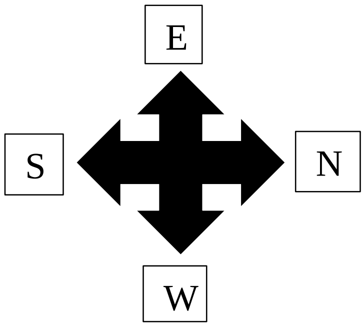
$T_7$= Silvery-grey colored Polythene (Mulch)

$T_8$= Black colored Polythene (Mulch)

### 3.9. Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) and 9 treatments including control with three replications. There were three blocks and each of the block in 27 unit plots. The size of each unit plot was 2.5×2 $m^2$. Plot to plot distances were maintained 0.5 m. The treatments were randomly distributed among the blocks.

- Total plot area: 271.625 $m^2$
- Number of plot: 27
- Plot size: 5.0 $m^2$
- Plot to plot distance (Lengthwise): 0.5 m
- Plot to plot distance (breadth wise): 0.75 m




**2.5x2=5 $m^2$**

| | | | | |
|---|---|---|---|---|
| **$T_5R_1$** (Red mulch) | **0.75m** | **$T_7R_1$** (Silvery-grey mulch) | **0.75m** | **$T_6R_2$** (Blue mulch) |
| **0.5m** | | | | |
| **$T_0R_3$** (Control) | | **$T_5R_2$** (Red mulch) | | **$T_3R_2$** (Maize) |
| | | | | |
| **$T_8R_1$** (Black mulch) | | **$T_2R_2$** (Linseed) | | **$T_4R_1$** (Coriander) |
| | | | | |
| **$T_7R_3$** (Silvery-grey mulch) | | **$T_1R_3$** (Sesame) | | **$T_2R_1$** (Linseed) |
| | | | | |
| **$T_4R_2$** (Coriander) | | **$T_4R_3$** (Coriander) | | **$T_7R_2$** (Silvery-grey mulch) |
| | | | | |
| **$T_2R_3$** (Linseed) | | **$T_6R_1$** (Blue mulch) | | **$T_5R_3$** (Red mulch) |
| | | | | |
| **$T_6R_3$** (Blue mulch) | | **$T_3R_1$** (Maize) | | **$T_8R_2$** (Black mulch) |
| | | | | |
| **$T_1R_1$** (Sesame) | | **$T_0R_2$** (Control) | | **$T_1R_2$** **(Sesame)** |
| | | | | |
| **$T_3R_3$** (Maize) | | **$T_8R_3$** (Black mulch) | | **$T_0R_1$** (Control) |

**Figure 4. Layout of experimental plot**

### 3.10. Land Preparation

The experiment's designated plot was power tilled, crossed-ploughed, and laddered multiple times to get a proper tilth. The clods were broken up into smaller pieces and the weeds and stubbles were removed to achieve the ideal soil conditions for seed germination. After final land preparation, the experimental plot was laid out.

### 3.11. Manure and Fertilizers Application

The experimental period did not involve the use of additional nitrogenous fertilizer because mungbean is a leguminous crop. Triple superphosphate (TSP) and muriate of potash (MOP) were used, respectively, as sources of $P_2O_5$ and $K_2O$ to keep the soil healthy. During the last stage of land preparation, the full amounts of TSP and MOP were applied. During the last stage of land preparation, well-decomposed cow dung (10 t $ha^{-1}$) was also used. By spading, the fertilizers were thoroughly incorporated into the soil, and the individual unit plots were leveled.

### 3.12. Seed Sowing

Seeds were sown in the main field on the 20$^{th}$ March, 2021 having line to line distance of 30 cm and plant to plant distance of 10 cm.

**Figure 5. Seed Sowing**

### 3.13. Intercultural Operations

Several intercultural operations, including plant thinning, gap filling, weeding, irrigation etc. were used throughout the entire experiment period to maintain the health of the plants and weed-free conditions in the field. Bird protection was given special attention, especially after sowing and at germination stages. The field ensured routine irrigation.

#### 3.13.1. Thinning

The seedlings were thinned out from the plot at 15 DAS.

#### 3.13.2. Irrigation

The plot was irrigated as per requirement.

#### 3.13.3. Weeding

Weeding was necessary to keep the plots free from weeds for easy aeration. Total five weeding were done to keep the plots free from weeds.

### 3.13.4. Mulching

Mulching was done as per recommendation on the selected plots.

**Figure 6. Mulching of experimental plot with different colored polythene mulches**

### 3.13.5. Drainage

Stagnant water was effectively drained out at the time of heavy rains.

### 3.14. Parameters Assessed

Data on following parameters were recorded from the selected plants:

- Disease incidence (%) per plot
- Disease incidence (%) per Plant
- Disease area index
- Plant height (cm)
- Number of plants per plot
- Number of infected plants per plot
- Number of infected leaves per infected plant
- Chlorophyll content

- Number of flower per plant
- Number of pod per plant
- Healthy Pod Length (cm)
- Infected Pod Length (cm)
- Number of seed/pod
- 1000-seed weight
- Yield (g/plot)

### 3.15. Data Collection

Different steps were performed to obtain data on various physiological and morphological aspects from the chosen plants. Data over the parameters were taken in the following ways-

#### 3.15.1. Disease incidence (%) per plot

Mungbean plants were checked daily and any symptoms that appear in the leaves were documented. Data collection on disease incidence was started just after the appearance of typical symptoms and continued up to three times with 15 days interval.

The growth stage of the plants were categorized as follows-

1. Early stage- 3 weeks after seed sowing
2. Mid stage- 2 weeks after early stage
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. The percent disease incidence was calculated using the following formula:

$$\% \text{ Disease Incidence} = \frac{\textbf{Number of Infected Plants}}{\textbf{Total number of Plants}} \times 100$$

### 3.15.2. Disease incidence (%) per plant

Incidence of mosaic diseases were recorded at before and after flowering. 24 plants were selected from eight lines from each plot and the mosaic symptoms on leaves were observed carefully for the collection of data. Data on mosaic disease incidence were recorded at an interval of 15 days commencing from first incidence and continued up to 3 times. The percent disease incidence per plant was calculated using the following formula:

$$\% \text{ Disease incidence} = \frac{\textbf{Number of Infected Leaves}}{\textbf{Total number of Leaves}} \text{ X } 100$$

### 3.15.3. Percent Disease Index

Ten randomly chosen plants from each plot were thoroughly examined to document the severity of mosaic diseases. Data on the severity of the mosaic disease were gathered every 15 days beginning with the initial severity and continuing up to three times.

The percent disease index was calculated using the following formula:

$$\text{Percent disease index (PDI)} = \frac{\textbf{Sum of all disease rating}}{\textbf{Total number of leaves observed X Highest grade in scale}} \text{ X } 100$$

The severity of the disease was graded using an arbitrary scale (Table 1) provided by Akhtar *et al*. (2009) based on the percentage of infected plants.

**Table 1. Disease scale based on disease severity (Akhtar *et al.*, 2009).**

| **Symptoms** | **Disease Severity** | **% Disease Index** | **Disease reaction** |
|---|---|---|---|
| Complete absence of symptoms | 0 | 0 | Highly Resistant |
| Few small yellow specks or spots on few leaves seen after careful observations. | 1 | 0.01-10 | Resistant |
| Bright yellow specks or spots common on leaves, easily observed and some Coalesced | 2 | 10.01-25 | Moderately Resistant |
| Mostly coalesced bright yellow specks or spots common on leaves, but no or minor reduction in yield | 3 | 25.01-40 | Moderately Susceptible |
| Plants showing coalesced bright yellow specks or spots on all leaves, with no or minor stunting and set fewer normal pods | 4 | 40.1-60 | Susceptible |
| Yellowing or chlorosis of all leaves on whole plant followed by necrosis, shortening of internode, severe stunting of plants with no yield or few flowers<br>& deformed pods produced with small, immature and shriveled seeds. | 5 | >60.01 | Highly Susceptible |

### 3.15.4. Plant height (cm)

The plant height was measured from the ground level to the top of the plant. Heights of 5 plants randomly selected plants from each plot were measured. It was done at the flowering stage of the crop (at 45 DAS).

### 3.15.5. Number of plants per plot

Number of plants from each plot at 30, 45 and 60 days after sowing (DAS) was recorded.

### 3.15.6. Number of infected plants per plot

Number of infected plants from each plot at 30, 45 and 60 days after sowing (DAS) was recorded.

### 3.15.7. Number of infected leaves per infected plant

Number of infected leaves of selected infected plants from each plot at 30, 45 and 60 days after sowing (DAS) was recorded. Calculating the average number of infected leaves, the average number was recorded.

### 3.15.8. Chlorophyll content

To ascertain the chlorophyll concentration, the Witham's Acetone Method, developed in 1996, was used.

- A separate polythene bag was used to collect and store the randomly chosen leaf samples.
- The leaf samples were taken right away to the lab for further analysis after collection.
- Leaf samples weighing around 20 mg were put into a glass vial with 20 ml of an 80% acetone solution.
- For 48 hours, the glass vials were in a dark environment.
- Chlorophyll was measured after 48 hours using a double beam spectrophotometer at 663 and 645 nm wavelength and the formula used to calculate chlorophyll is as follows:

$$\text{Chlorophyll (a+b) mg g}^{-1}\text{ leaf tissue} = \frac{[20.2\,(D645) + 8.02\,(D663)]\ X\ V}{1000\ X\ W}$$

Where,

D = optical density of the chlorophyll extract at 663 and 645 nm wavelengths

V= final volume (ml) of the chlorophyll extract in 80% acetone

W= Fresh sample weight in g

Both tabular and graphical presentation of the data were used.

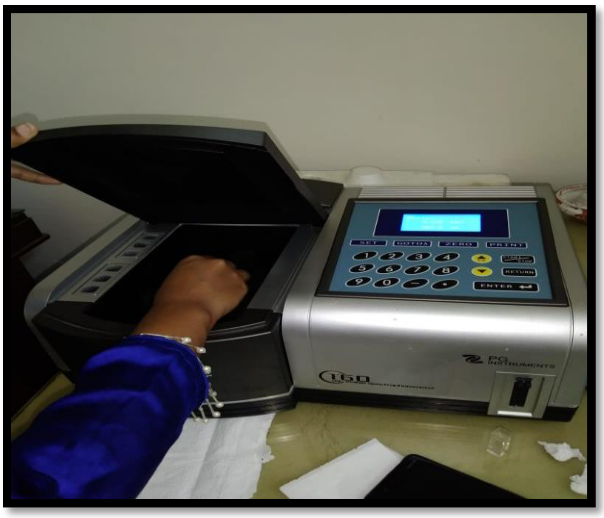



**Figure 7. Chlorophyll content determination using acetone method**

### 3.15.9. Number of flower per plot

Mean number of flower of selected plants from each plot as per treatment combination was recorded.

### 3.15.10. Harvesting

First harvest was done on 29$^{th}$ May, 2021 and final harvest was done on 12$^{th}$ June, 2021 when the crop was matured. The harvested crop of each plot was bundled separately. Pods that had been harvested were threshed, and grains had been dried to guard against pathogenic assaultion. Grains were recorded as plot wise and the yields were expressed in gram (g) per plot.

### 3.15.11. Number of pod per plot

Pods were counted at the ripening stage. Pods of 5 randomly selected plants from each plot were harvested separately in three times. Total number of harvested pods in each time from each of the plant were counted and averaged.

### 3.15.12. Healthy Pod Length (cm)

It was done after harvest. Firstly 5 plants per plot were selected randomly. Then length of 5 pods from each plant were measured and averaged.

### 3.15.13. Infected Pod Length (cm)

It was done after harvest. Firstly 5 diseased plants per plot were selected randomly. Then length of 5 diseased pods from each diseased plant were measured and averaged.

### 3.15.14. Number of seeds per pod

It was done after harvest. Firstly 5 pods per plot were selected randomly. Number of seeds $pod^{-1}$ was counted for both healthy and diseased pods. Sum of the seeds of the selected pods from each plot were counted and averaged.

### 3.15.15. 1000-seed weight

Firstly, harvested pods were dried and threshed and then 1000 seeds from each plot were counted and weighed.

### 3.15.16. Yield (g/plot)

Harvested pods were dried and threshed firstly. Grains obtained from each plot (5.0 $m^2$) were dried, weighed carefully.

### 3.16. Statistical Analysis

The data was analyzed by using the "Statistix-10" Software latest version. The mean value was compared according to LSD range test at 5% level of significance. Tables, bar diagram, linear graphs and photographs were used to present the data as and when necessary.

# CHAPTER IV

# RESULTS AND DISCUSSION

The experiment was conducted to manage *Mungbean Yellow Mosaic Virus (MYMV)* using barrier crops and colored plastic mulches under field condition. The results of the present study are compiled based on disease incidence, disease area index, morphological and physiological parameters at 30, 45, 60 days after sowing (DAS) are presented in this chapter.

## 4.1. Effect of barrier crops and colored plastic mulches on disease incidence (%) per plot

Disease incidence plot$^{-1}$ was recorded at 30, 45, 60 days after sowing (DAS) after the application of different treatments *viz.*; $T_0$ (Control), $T_1$ (Sesame), $T_2$ (Linseed), $T_3$ (Maize), $T_4$ (Coriander), $T_5$ (Red), $T_6$ (Blue), $T_7$ (Silvery-grey), $T_8$ (Black) in BINAmoog-5.

At 30 DAS, the disease incidence range was varied from 5.35% to 25.92%. The lowest disease incidence was observed in $T_3$ (5.35%) followed by $T_1$ (6.21%) which were statistically identical. The highest disease incidence was recorded in $T_0$ (25.92%). The moderate disease incidence was found in $T_4$ (14.10%) followed by $T_2$ (12.30%), $T_6$ (11.93%), $T_5$ (10.33%), $T_8$ (9.75%) and $T_7$ (8.56%) which were statistically identical to each other.

At 45 DAS, the disease incidence range was varied from 8.95% to 35.52%. The lowest disease incidence was revealed in $T_3$ (8.95%) followed by $T_1$ (10.04%). The highest disease incidence was recorded in $T_0$ (35.52%) and the second highest disease incidence was found in $T_6$ (25.58%) followed by $T_4$ (22.10%).

The moderate disease incidence was recorded in $T_7$ (14.35%), $T_8$ (15.32%), $T_5$ (17.02%), $T_2$ (17.64%). Treatment $T_7$ (14.35%) and $T_8$ (15.32%) were statistically similar with each other and treatment $T_5$ (17.02%) and $T_2$ (17.64%) were statistically similar with each other.

At 60 DAS, the disease incidence range was varied from 17.91% to 61.10%. The lowest disease incidence was observed in $T_3$ (17.91%) followed by $T_1$ (20.64%) which were statistically different. The highest disease incidence was found in $T_0$ (61.10%) followed by $T_4$ (36.67%) and $T_6$ (34.96%). The moderate disease incidence was recorded in $T_2$ (29.29%) and $T_5$ (28.50%) which were statistically similar with each other but different from $T_8$ (25.44%) and $T_7$ (23.91%). Treatment $T_8$ (25.44%) and $T_7$ (23.91%) were statistically similar with each other.

**Table 2. Effect of different treatments on disease incidence plot$^{-1}$ at 30, 45 and 60 DAS against *Mungbean yellow mosaic virus (MYMV)***

| Treatment | % Disease Incidence Plot$^{-1}$ at | | |
|---|---|---|---|
| | 30 DAS | 45 DAS | 60 DAS |
| $T_0$ | 25.92 a | 35.52 a | 61.10 a |
| $T_1$ | 6.21 ef | 10.04 f | 20.64 e |
| $T_2$ | 12.30 bc | 17.64 d | 29.29 c |
| $T_3$ | 5.35 f | 8.95 f | 17.91 f |
| $T_4$ | 14.10 b | 22.10 c | 36.67 b |
| $T_5$ | 10.33 cd | 17.02 d | 28.50 c |
| $T_6$ | 11.93 bc | 25.58 b | 34.96 b |
| $T_7$ | 8.56 de | 14.35 e | 23.91 d |
| $T_8$ | 9.75 cd | 15.32 e | 25.44 d |
| CV (%) | 13.14 | 5.18 | 4.24 |

Here, $T_0$= Control, $T_1$= Sesame, $T_2$= Linseed, $T_3$= Maize, $T_4$= Coriander, $T_5$= Red plastic mulch, $T_6$= Blue plastic mulch, $T_7$= Silvery-grey plastic mulch, $T_8$= Black plastic mulch

**Figure 8. Disease Incidence at 30 DAS**

**Figure 9. Disease Incidence at 45 DAS**

**Figure 10. Disease Incidence at 60 DAS**

## 4.2. Effect of barrier crops and colored plastic mulches on disease incidence (%) per plant

Disease incidence plot$^{-1}$ was also recorded at 30, 45 and 60 DAS against *Mungbean yellow mosaic virus* which were statistically identical.

At 30 DAS, the disease incidence range was varied from 5.24% to 27.66%. The lowest disease incidence was observed in $T_3$ (5.24%) followed by $T_1$ (6.73%) which were statistically identical to each other. The highest disease incidence was recorded in $T_0$ (27.66%) which showed statistically different result from others. The moderate disease incidence was revealed in $T_7$ (8.23%), $T_8$ (9.35%), $T_5$ (10.91%), $T_2$ (14.05%), $T_6$ (16.73%) and $T_4$ (17.65%).

At 45 DAS, the disease incidence rate was varied from 11.75% to 34.15%. The lowest disease incidence were observed in $T_3$ (11.75%) followed by $T_1$ (12.86%) which were statistically similar with each other. The highest disease incidence was found in $T_0$ (34.15%) which was statistically different from others. The moderate disease incidence were recorded in $T_7$ (15.76%), $T_8$ (18.03%), $T_2$ (19.83%), $T_5$ (21.21%), $T_4$ (26.08%) and $T_6$ (26.29%). Treatment $T_2$ (19.83%) and $T_5$ (21.21%) were statistically similar but different from treatment $T_7$ (15.76%) and $T_8$ (18.03%). Treatment $T_4$ (26.08%) and $T_6$ (26.29%)were statistically similar with each other.

At 60 DAS, the disease incidence range was varied from 19.09% to 59.72%. The lowest disease incidence was recorded in $T_3$ (19.09%) followed by $T_1$ (21.93%) which were statistically different. The highest disease incidence was observed in $T_0$ (59.72%) and second highest was found in $T_6$ (40.00%) followed by $T_4$ (36.58 %) which were statistically different from each other. The moderate disease incidence were revealed in $T_2$ (29.85%), $T_5$ (29.26%), $T_8$ (27.65%) and $T_7$ (24.70%). Treatment $T_2$ (29.85%), $T_5$ (29.26%) were statistically similar with each other but different from treatment $T_7$ (24.70%) and $T_8$ (27.65%).

**Table 3. Effect of different treatments on disease incidence plant$^{-1}$ at 30, 45 and 60 DAS against *Mungbean yellow mosaic virus (MYMV)***

| Treatment | % Disease Incidence Plant$^{-1}$ | | |
|---|---|---|---|
| | At 30 DAS | At 45 DAS | At 60 DAS |
| $T_0$ | 27.66 a | 34.15 a | 59.72 a |
| $T_1$ | 6.73 fg | 12.86 f | 21.93 f |
| $T_2$ | 14.05 c | 19.83 c | 29.85 d |
| $T_3$ | 5.24 g | 11.75 f | 19.09 g |
| $T_4$ | 17.65 b | 26.08 b | 36.58 c |
| $T_5$ | 10.91 d | 21.21 c | 29.26 d |
| $T_6$ | 16.73 b | 26.29 b | 40.00 b |
| $T_7$ | 8.23 ef | 15.76 e | 24.70 e |
| $T_8$ | 9.35 de | 18.03 d | 27.65 d |
| CV (%) | 7.25 | 4.86 | 4.18 |

Here, $T_0$= Control, $T_1$= Sesame, $T_2$= Linseed, $T_3$= Maize, $T_4$= Coriander, $T_5$= Red plastic mulch, $T_6$= Blue plastic mulch, $T_7$= Silvery-grey plastic mulch, $T_8$= Black plastic mulch

### 4.3. Percent Disease Index (PDI)

Percent disease index were measured at 30, 45, 60 days after sowing (DAS) after the application of different treatments *viz*., $T_0$ (Control), $T_1$ (Sesame), $T_2$ (Linseed), $T_3$ (Maize), $T_4$ (Coriander), $T_5$ (Red), $T_6$ (Blue), $T_7$ (Silvery-grey), $T_8$ (Black) in BINAmoog-5.

At 30 DAS, the percent disease index range was varied from 5.55% to 28.14%. The lowest percent disease index was observed in $T_3$ (5.55%) followed by $T_1$ (5.73%) which were statistically similar with each other. The highest percent disease index was recorded in $T_0$ (28.14%). The moderate percent disease index were found in $T_7$ (7.42%), $T_5$ (7.77 %) followed by $T_8$ (8.73%), $T_2$ (9.24%), $T_6$ (10.70%) and $T_4$ (11.11%). Treatment $T_7$ (7.42%), $T_5$ (7.77 %) were statistically similar with each other and treatment $T_4$ (11.11%), $T_6$ (10.70%) were statistically similar with each other.

At 45 DAS, the percent disease index range was varied from 13.39% to 37.71%. The lowest percent disease index was observed in $T_3$ (13.39 %) followed by $T_1$ (14.66 %) which were statistically similar with each other. The highest percent disease index was found in $T_0$ (37.71%). The moderate percent disease index were revealed in $T_8$ (17.90%), $T_7$ (17.97%), $T_5$ (18.26 %), $T_2$ (20.61%) followed by $T_6$ (26.84%) and $T_4$ (26.93%). Treatment $T_7$ (17.97%) and $T_8$ (17.90%) were statistically similar with each other and treatment $T_4$ (26.93%) and $T_6$ (26.84%) were statistically similar with each other.

At 60 DAS, the percent disease index range was varied from 20.16% to 64.08%. The lowest percent disease index was observed in $T_3$ (20.16%) followed by $T_1$ (21.66%) which were statistically similar with each other. The highest percent disease index was found in $T_0$ (64.08%). The moderate percent disease index were seemed in $T_7$ (26.70%), $T_8$ (28.00%), $T_5$ (28.53%) followed by $T_2$ (32.21%), $T_4$ (36.81%) and $T_6$ (37.92%). Treatment $T_7$ (26.70%), $T_8$ (28.00%), $T_5$ (28.53%) were statistically similar with each other and treatment $T_4$ (36.81%), $T_6$ (37.92%) were statistically similar with each other.

**Table 4. Effect of different treatments on Percent Disease Index at 30, 45 and 60 DAS against *Mungbean yellow mosaic virus (MYMV)***

| **Treatment** | **Percent Disease Index (PDI)** | | |
|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** |
| $T_0$ | 28.14 a | 37.71 a | 64.08 a |
| $T_1$ | 5.73 e | 14.66 e | 21.66 e |
| $T_2$ | 9.24 c | 20.61 c | 32.21 c |
| $T_3$ | 5.55 e | 13.39 e | 20.16 e |
| $T_4$ | 11.11 b | 26.93 b | 36.81 b |
| $T_5$ | 7.77 d | 18.26 d | 28.53 d |
| $T_6$ | 10.70 b | 26.84 b | 37.92 b |
| $T_7$ | 7.42 d | 17.97 d | 26.70 d |
| $T_8$ | 8.73 cd | 17.90 d | 28.00 d |
| CV (%) | 7.72 | 5.77 | 3.75 |

Here, $T_0$= Control, $T_1$= Sesame, $T_2$= Linseed, $T_3$= Maize, $T_4$= Coriander, $T_5$= Red plastic mulch, $T_6$= Blue plastic mulch, $T_7$= Silvery-grey plastic mulch, $T_8$= Black plastic mulch

**Figure 11. Percent Disease Index at 30 DAS**

**Figure 12. Percent Disease Index at 45 DAS**

**Figure 13. Percent Disease Index at 60 DAS**

## 4.4. Effect of different treatments on morphological characters

### 4.4.1. Plant height (cm)

Plant height was recorded at 45 DAS. From the experiment it was observed that the maximum plant height was recorded in $T_3$ (69.73cm) followed by $T_1$ (68.20cm) and $T_7$ (67.40cm) which were statistically similar with each other. The minimum plant height was recorded in $T_0$ (53.20cm). The moderate plant height was recorded in $T_8$ (60.46cm), $T_2$ (58.73cm), $T_5$ (57.53cm), $T_4$ (57.10cm) and $T_6$ (55.86cm) which were statistically identical to each other.

### 4.4.2. Number of branches per plant

Number of branches was recorded at 45 DAS. From the study it was observed that maximum number of branches per plant was recorded in $T_3$ (8.00) followed by $T_1$ (7.80) and $T_7$ (7.80) which were statistically identical to each other. Treatment $T_1$ (7.80) and $T_7$ (7.80) were statistically similar to each other. The minimum number of branches per plant was recorded in $T_4$ (6.80) followed by $T_0$ (6.86) and $T_6$ (6.86) which were statistically similar with each other. The moderate number of branches was recorded in $T_2$ (7.33) followed by $T_8$ (7.26) and $T_5$ (7.23) which were statistically identical to each other.

### 4.4.3. Number of flowers per plant

The maximum number of flowers plant$^{-1}$ was recorded in $T_3$ (29.60) followed by $T_1$ (29.26). The minimum number of flowers per plant was recorded in $T_0$ (13.23). The moderate number of flowers per plant was recorded in $T_7$ (26.50) followed by $T_8$ (23.86), $T_4$ (20.60), $T_2$ (20.10), $T_5$ (19.46) and $T_6$ (17.66). Treatment $T_7$ (26.50), $T_8$ (23.86), $T_4$ (20.60) were statistically identical to each other but different from treatment $T_2$ (20.10), $T_5$ (19.46) and $T_6$ (17.66).

Treatment $T_2$ (20.10), $T_5$ (19.46) and $T_6$ (17.66) were statistically similar with each other.

### 4.4.4. Number of healthy leaves per plant

The maximum number of healthy leaves plant$^{-1}$ was observed in $T_3$ (23.93) followed by $T_1$ (21.63) which were statistically identical to each other. The minimum number of healthy leaves was found in $T_0$ (9.33). The moderate number of healthy leaves was recorded in $T_7$ (20.93) followed by $T_8$ (19.53), $T_2$ (14.80), $T_5$ (14.66), $T_6$ (12.86) and $T_4$ (12.20). Treatment $T_7$ (20.93), $T_8$ (19.53) were statistically similar with each other and treatment $T_2$ (14.80), $T_5$ (14.66), $T_6$ (12.86), $T_4$ (12.20) were statistically similar with each other.

### 4.4.5. Number of infected leaves per plant

The highest number of infected leaves was revealed in $T_0$ (13.26) and the lowest number of infected leaves was found in $T_3$ (5.20). The moderate number of infected leaves was observed in $T_1$ (6.867) preceded by $T_7$ (7.06), $T_8$ (7.93), $T_5$ (10.46), $T_6$ (10.60), $T_2$ (11.40) and $T_4$ (11.66). Treatment $T_5$ (10.46), $T_6$ (10.60), $T_2$ (11.40) and $T_4$ (11.66) were statistically identical to each other. Treatment $T_1$ (6.867), $T_7$ (7.06), $T_8$ (7.93) were statistically identical to each other but different from others.

**Table 5. Effect of different treatments on Plant height, Number of branches per plant, Number of flowers per plant, Number of healthy leaves per plant and Number of infected leaves per plant against *Mungbean yellow mosaic virus (MYMV)***

| Treatment | Plant Height (cm) | No of Branches / Plant | No of Flowers / Plant | No of Healthy Leaves / Plant | No of Infected leaves / Plant |
|---|---|---|---|---|---|
| $T_0$ | 53.20 d | 6.86 c | 13.23 e | 9.33 d | 13.26 a |
| $T_1$ | 68.20 a | 7.80 ab | 29.26 a | 21.63 ab | 6.86 c |
| $T_2$ | 58.73 bc | 7.33 abc | 20.10 d | 14.80 c | 11.40 b |
| $T_3$ | 69.73 a | 8.00 a | 29.60 a | 23.93 a | 5.20 d |
| $T_4$ | 57.10 bcd | 6.80 c | 20.60 cd | 12.20 c | 11.66 b |
| $T_5$ | 57.53 bc | 7.23 bc | 19.46 d | 14.66 c | 10.46 b |
| $T_6$ | 55.86 cd | 6.86 c | 17.66 d | 12.86 c | 10.60 b |
| $T_7$ | 67.40 a | 7.80 ab | 26.50 ab | 20.93 b | 7.06 c |
| $T_8$ | 60.46 b | 7.26 bc | 23.86 bc | 19.53 b | 7.93 c |
| CV (%) | 3.87 | 5.77 | 8.69 | 9.16 | 8.93 |

Here, $T_0$= Control, $T_1$= Sesame, $T_2$= Linseed, $T_3$= Maize, $T_4$= Coriander, $T_5$= Red plastic mulch, $T_6$= Blue plastic mulch, $T_7$= Silvery-grey plastic mulch, $T_8$= Black plastic mulch

### 4.4.6. Number of pods per plant

The highest number of pods per plant$^{-1}$ was recorded under the treatment of $T_3$ (26.13) and second highest number of pods per plant was $T_1$ (25.73) followed by $T_7$ (21.60) and $T_8$ (20.66). Treatment $T_3$ (26.13) and $T_1$ (25.73) were statistically identical to each other but different from treatment $T_7$ (21.60) and $T_8$ (20.66).

Treatment $T_7$ (21.60) and $T_8$ (20.66) were statistically identical to each other. The lowest number of pods per plant was recorded in $T_0$ (11.60) which was statistically different from others. The moderate number of pods per plant was recorded in $T_2$ (17.80) followed by $T_5$ (17.26), $T_4$ (16.46) and $T_6$ (15.33).

### 4.4.7. Healthy pod length (cm)

The maximum length of healthy pod was recorded in $T_3$ (8.84 cm) followed by $T_1$ (8.76 cm), $T_7$ (7.67 cm), $T_8$ (7.57 cm), $T_5$ (7.50 cm), $T_2$ (7.09 cm), $T_6$ (7.03 cm) and $T_4$ (7.03 cm). Treatment $T_3$ (8.84 cm), $T_1$ (8.76 cm) were statistically similar with each other, treatment $T_7$ (7.67 cm), $T_8$ (7.57 cm), $T_5$ (7.50 cm) were statistically similar with each other and treatment $T_2$ (7.09 cm), $T_6$ (7.03 cm), $T_4$ (7.03 cm) were statistically similar with each other. The minimum length of healthy pod was observed in $T_0$ (5.70 cm) which was statistically different from others.

### 4.4.8. Infected pod length (cm)

The maximum length of infected pod was revealed in $T_3$ (6.78 cm) followed by $T_1$ (6.65 cm) which were statistically similar to each other. The minimum length of infected was observed in $T_0$ (4.18 cm) preceded by $T_2$ (5.04 cm), $T_4$ (5.12 cm), $T_6$ (5.36 cm), $T_8$ (5.38 cm), $T_5$ (5.44 cm) and $T_7$ (5.82 cm).

### 4.4.9. Number of healthy seeds per pod

The highest number of healthy seeds pod$^{-1}$ was observed in $T_3$ (12.66) and second highest was recorded in $T_1$ (12.46) followed by $T_5$ (11.46), $T_2$ (11.40), $T_7$

(11.40) and $T_8$ (11.40). Treatment $T_3$ (12.66) and $T_1$ (12.46) were statistically similar to each other and treatment $T_2$ (11.40), $T_7$ (11.40) and $T_8$ (11.40) were statistically similar to each other. The lowest number of healthy pods was recorded $T_0$ (7.26) preceded by $T_4$ (9.13) and $T_6$ (9.73).

### 4.4.10. Number of deformed per seeds pod

The highest number of deformed pod was recorded in $T_0$ (6.33) followed by $T_4$ (5.86) and $T_2$ (5.67). The lowest number of deformed seeds per pod was observed in $T_1$ (4.21) preceded by $T_3$ (4.29), $T_7$ (5.13), $T_5$ (5.33), $T_6$ (5.58) and $T_8$ (5.62). Treatment $T_1$ (4.21), $T_3$ (4.29) were statistically similar with each other and treatment $T_6$ (5.58), $T_8$ (5.62) were statistically similar with each other.

**Table 6. Effect of different treatments on Number of pods per plant, Length of healthy pod, Length of infected pod, Number of healthy seeds per Pod and Number of deformed seeds pod$^{-1}$ against *Mungbean yellow mosaic virus (MYMV)***

| Treatment | Number of pods/ plant | Length of healthy pod (cm) | Length of infected pod (cm) | Number of healthy seeds/ pod | Number of deformed seeds/ pod |
|---|---|---|---|---|---|
| $T_0$ | 11.60 e | 5.70 d | 4.18 f | 7.26 e | 6.33 a |
| $T_1$ | 25.73 a | 8.76 a | 6.65 a | 12.46 a | 4.21 f |
| $T_2$ | 17.80 c | 7.09 c | 5.04 e | 11.40 b | 5.67 bc |
| $T_3$ | 26.13 a | 8.84 a | 6.78 a | 12.66 a | 4.29 f |
| $T_4$ | 16.46 cd | 6.89 c | 5.12 de | 9.13 d | 5.86 b |
| $T_5$ | 17.26 cd | 7.50 b | 5.44 c | 11.46 b | 5.33 d |
| $T_6$ | 15.33 d | 7.03 c | 5.36 cd | 9.73 cd | 5.58 c |
| $T_7$ | 21.60 b | 7.67 b | 5.82 b | 11.40 b | 5.13 e |
| $T_8$ | 20.66 b | 7.57 b | 5.38 cd | 11.40 b | 5.62 c |
| CV (%) | 5.97 | 1.73 | 2.83 | 4.35 | 2.01 |

Here, $T_0$= Control, $T_1$= Sesame, $T_2$= Linseed, $T_3$= Maize, $T_4$= Coriander, $T_5$= Red plastic mulch, $T_6$= Blue plastic mulch, $T_7$= Silvery-grey plastic mulch, $T_8$= Black plastic mulch

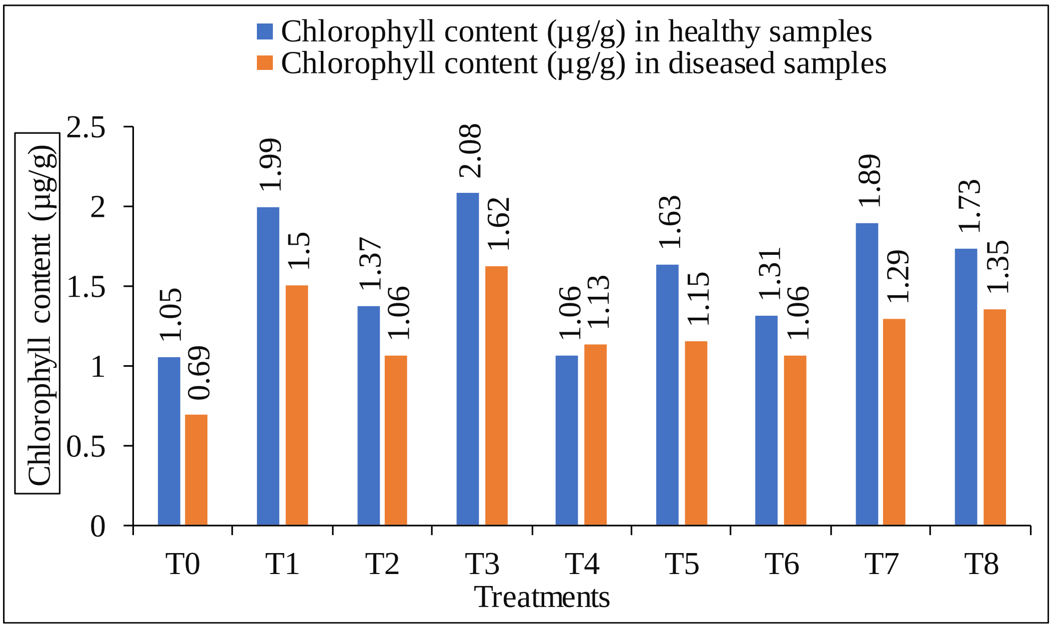
## 4.5. Effect of different treatments on physiological features

### Chlorophyll content (µg/g) of healthy plant and infected plant

The Witham formula, often known as the "Acetone technique," was used to determine the chlorophyll concentration. Chlorophyll concentration of the plant revealed a significant difference between the various treatments at 45DAS.

In healthy plants, the highest chlorophyll content was found in $T_3$ (2.0871 µg/g) followed by $T_1$ (1.9955 µg/g), $T_7$ (1.8984 µg/g), $T_8$ (1.7836 µg/g), $T_5$ (1.6301 µg/g), $T_6$ (1.3157 µg/g), $T_2$ (1.3717 µg/g) and $T_4$ (1.0611 µg/g). The lowest chlorophyll content was recorded in $T_0$ (1.0554 µg/g) which was statistically similar with treatment $T_4$ (1.0611 µg/g), $T_6$ (1.3157 µg/g) and $T_2$ (1.3717 µg/g) but different from others. Treatment $T_3$ (2.0871 µg/g), $T_1$ (1.9955 µg/g), $T_7$ (1.8984 µg/g) and $T_8$ (1.7836 µg/g) were statistically identical with each other.

In infected plants, the highest chlorophyll content was observed in $T_3$ (1.62 µg/g) followed by $T_1$ (1.50 µg/g), $T_8$ (1.35 µg/g), $T_7$ (1.29 µg/g), $T_5$ (1.15 µg/g), $T_4$ (1.13 µg/g), $T_2$ (1.06 µg/g) and $T_6$ (1.06 µg/g). The lowest chlorophyll content was recorded in $T_0$ (0.69 µg/g) which was statistically identical with $T_2$ (1.06 µg/g) and $T_6$ (1.06 µg/g) but different from others.




Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 14. Graphical representation of chlorophyll content (µg $g^{-1}$) in healthy and diseased samples**

### 4.6. Effect of different treatments on yield

#### 4.6.1. Effect of different treatments on 1000 seed weight

Several treatments significantly affected the weight of 1000 seeds. The weight of 1000 seeds varied between 37.907 g and 35.033 g depending on different treatments. The maximum weight was recorded in $T_3$ (37.907 g) preceded by $T_8$ (37.773 g), $T_7$ (37.393 g) and $T_1$ (37.253 g) which were statistically identical to each other. The minimum weight was recorded in $T_4$ (35.033 g) followed by $T_6$ (35.187 g), $T_0$ (35.297 g), $T_2$ (35.657 g), $T_5$ (36.477 g) and $T_5$ (36.477 g) was significantly different from others.

### 4.6.2. Effect of different treatments on yield (g/plot)

Amongst the various treatments, there was a significant difference in the yield per plot. The yield range varied between 615.32 g and 376.27 g depending on various treatments. The highest yield was observed in T3 (615.32 g) followed by T1 (608.10 g), T7 (569.12 g) which were statistically identical to each other and no significant variation was found among them. The lowest yield was revealed in T0 (376.27 g) followed by T4 (377.87 g), T2 (418.23 g), T8 (418.32 g), T6 (466.53 g), T5 (498.08 g) which were statistically identical to each other.

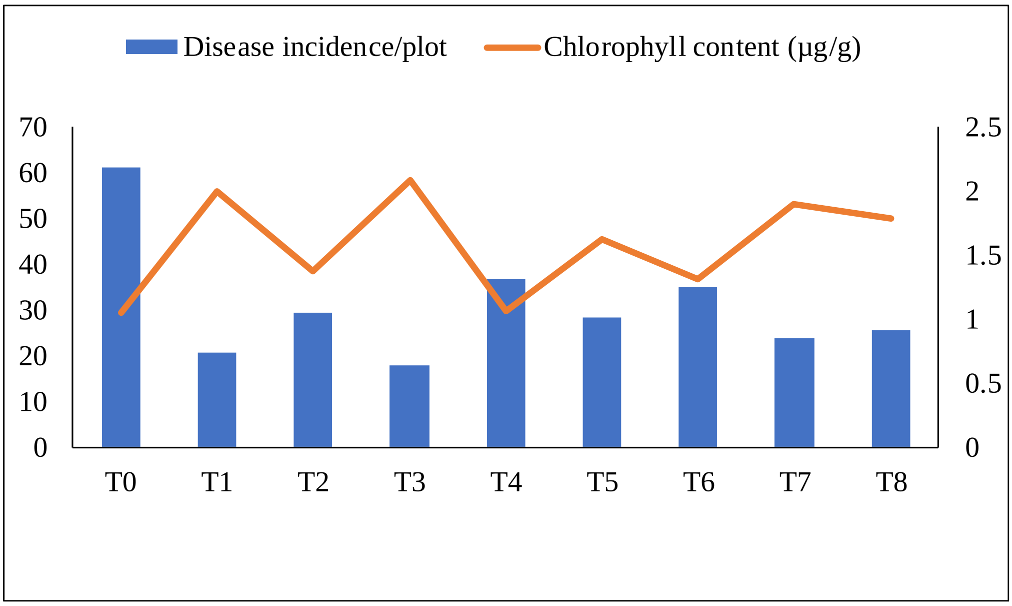
**Table 7. Effect of different treatments on 1000 seed weight and yield per plot against *Mungbean yellow mosaic virus (MYMV)***

| Treatment | 1000 seed weight (g) | Yield (g $plot^{-1}$) |
|---|---|---|
| $T_0$ | 35.29 c | 376.27 d |
| $T_1$ | 37.25 a | 608.10 a |
| $T_2$ | 35.65 c | 418.23 cd |
| $T_3$ | 37.90 a | 615.32 a |
| $T_4$ | 35.03 c | 377.87 d |
| $T_5$ | 36.47 b | 498.08 bc |
| $T_6$ | 35.18 c | 466.53 bcd |
| $T_7$ | 37.39 a | 569.12 ab |
| $T_8$ | 37.77 a | 418.32 cd |
| CV (%) | 1.07 | 12.28 |

Here, $T_0$= Control, $T_1$= Sesame, $T_2$= Linseed, $T_3$= Maize, $T_4$= Coriander, $T_5$= Red plastic mulch, $T_6$= Blue plastic mulch, $T_7$= Silvery-grey plastic mulch, $T_8$= Black plastic mulch

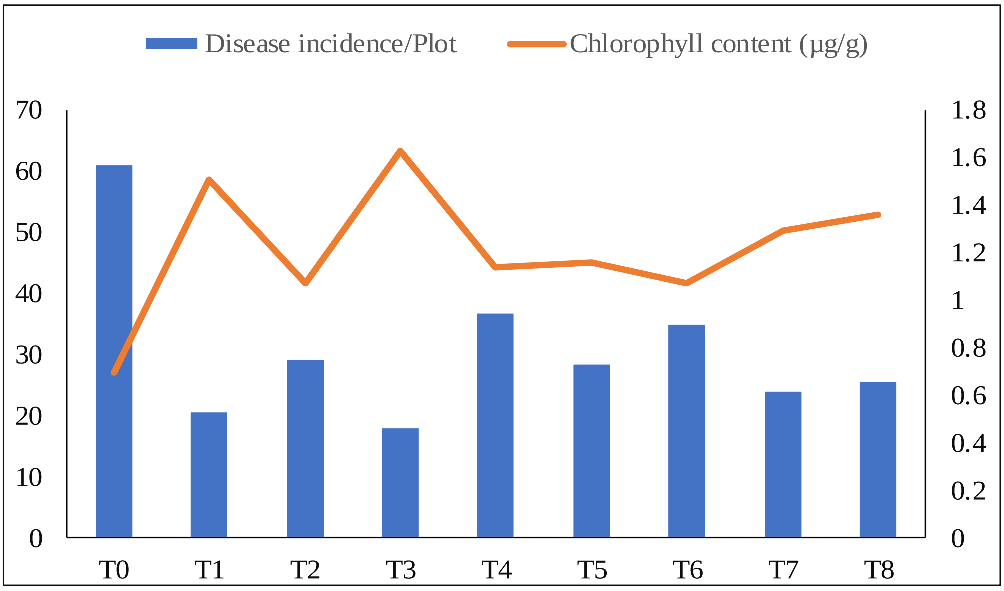
### 4.7. Relationship between chlorophyll content (μg $g^{-1}$) and disease incidence (%) per plot

From the relationship study between chlorophyll content (μg $g^{-1}$) and disease incidence (%) per plot, it was revealed that higher chlorophyll content (μg $g^{-1}$) was found with lower disease incidence (%). Minimum plot wise disease incidence (17.91%) was observed when maize was used as a barrier crop that found maximum chlorophyll content (2.08 μg $g^{-1}$) in healthy samples as well as in diseased samples (1.62 μg $g^{-1}$). Maximum plot wise disease incidence was seemed in control treatment (61.10%) that found minimum chlorophyll content (1.05 μg $g^{-1}$) in healthy samples as well as in diseased samples (0.69 μg $g^{-1}$).




Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 15. Relationship between Disease incidence plot$^{-1}$ and Chlorophyll content (μg $g^{-1}$) in healthy samples**

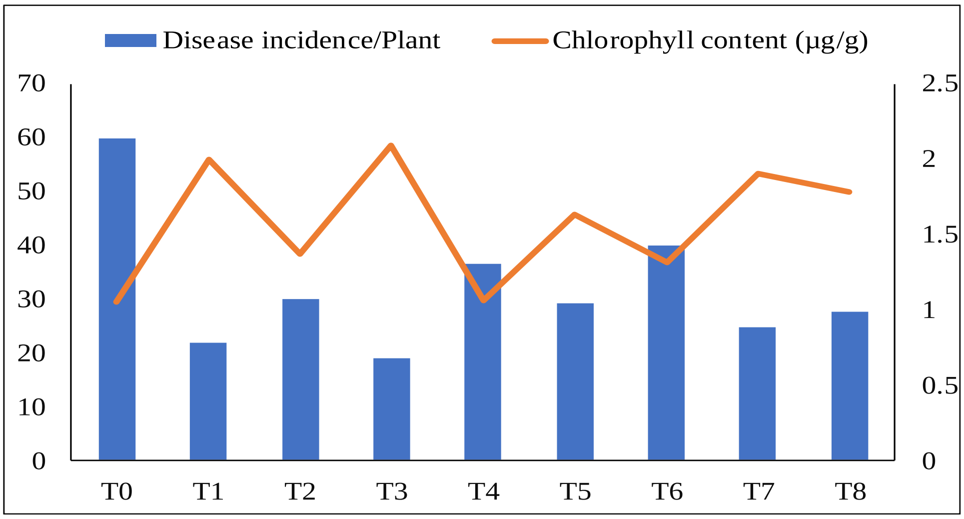



Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 16. Relationship between Disease incidence plot$^{-1}$ and Chlorophyll content (µg g$^{-1}$) in diseased samples**

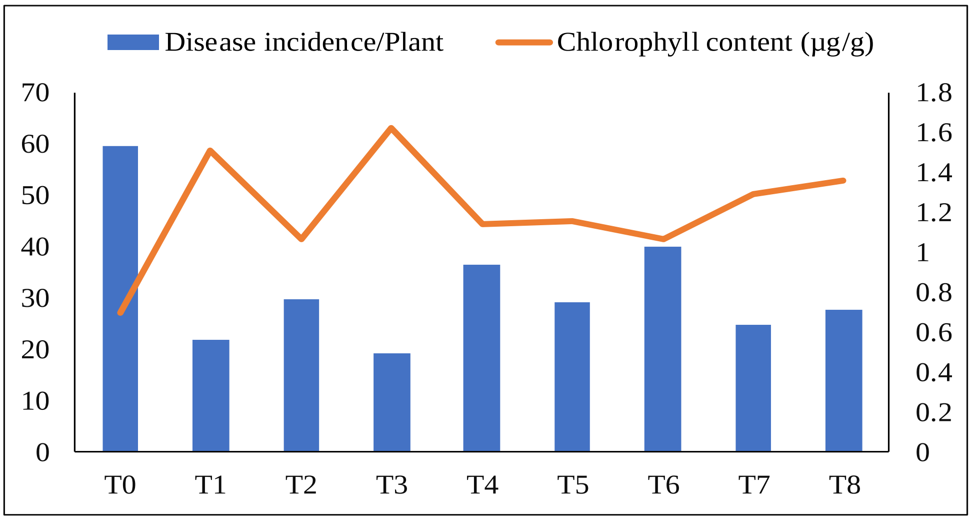
### 4.8. Relationship between chlorophyll content (µg g$^{-1}$) and disease incidence (%) per plant

From the relationship study between chlorophyll content (µg g$^{-1}$) and disease incidence (%) per plant, it was revealed that higher chlorophyll content (µg g$^{-1}$) was found with lower disease incidence (%) per plant. Minimum plant wise disease incidence (19.09%) was recorded when maize was used as a barrier crop that found maximum chlorophyll content (2.08 µg g$^{-1}$) in healthy samples as well as in diseased samples (1.62 µg g$^{-1}$). Maximum plant wise disease incidence was recorded in control treatment (59.72%) which showed minimum chlorophyll content (1.05 µg g$^{-1}$) in $T_0$ (1.05 µg g$^{-1}$) in healthy samples as well as in diseased samples (0.69 µg g$^{-1}$).




Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 17. Relationship between Disease incidence plant$^{-1}$ and Chlorophyll content (µg g$^{-1}$) in healthy samples**

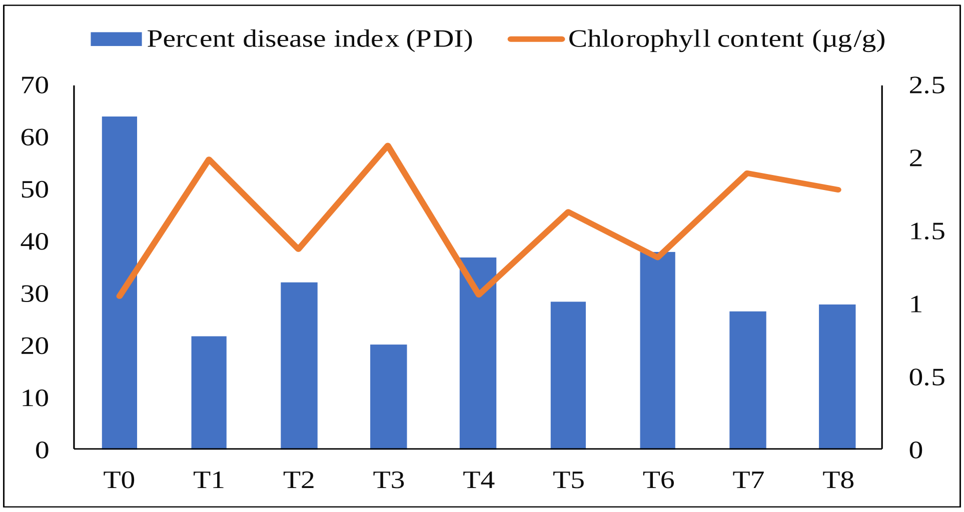



Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 18. Relationship between Disease incidence plant$^{-1}$ and Chlorophyll content (µg g$^{-1}$) in diseased sample**

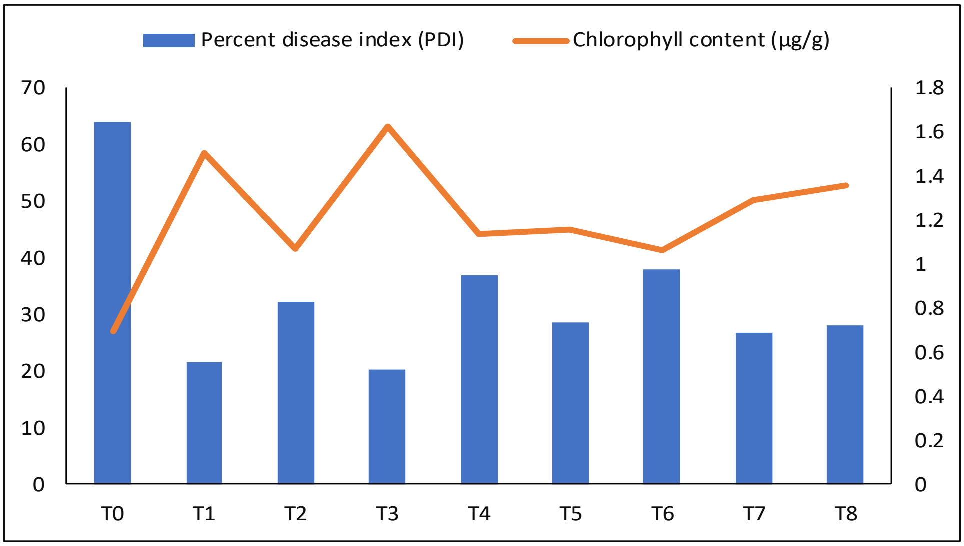
## 4.9. Relationship between chlorophyll content (µg $g^{-1}$) and percent disease index

The data of percent disease index and chlorophyll content (µg $g^{-1}$) revealed inverse relationship. From the relationship study between chlorophyll content (µg $g^{-1}$) and percent disease index (%), it was revealed that higher chlorophyll content (µg $g^{-1}$) was found with lower percent disease index (%). Minimum percent disease index (20.16%) was recorded when maize was used as a barrier crop that found maximum chlorophyll content (2.08 µg $g^{-1}$) in healthy samples as well as in diseased samples (1.62 µg $g^{-1}$). Maximum plot wise percent disease index was recorded in control treatment (64.08%) which showed minimum chlorophyll content (1.05 µg $g^{-1}$) in healthy samples as well as in diseased samples (0.69 µg $g^{-1}$).




Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 19. Relationship between Percent Disease Index and Chlorophyll Content (µg $g^{-1}$) in healthy samples**

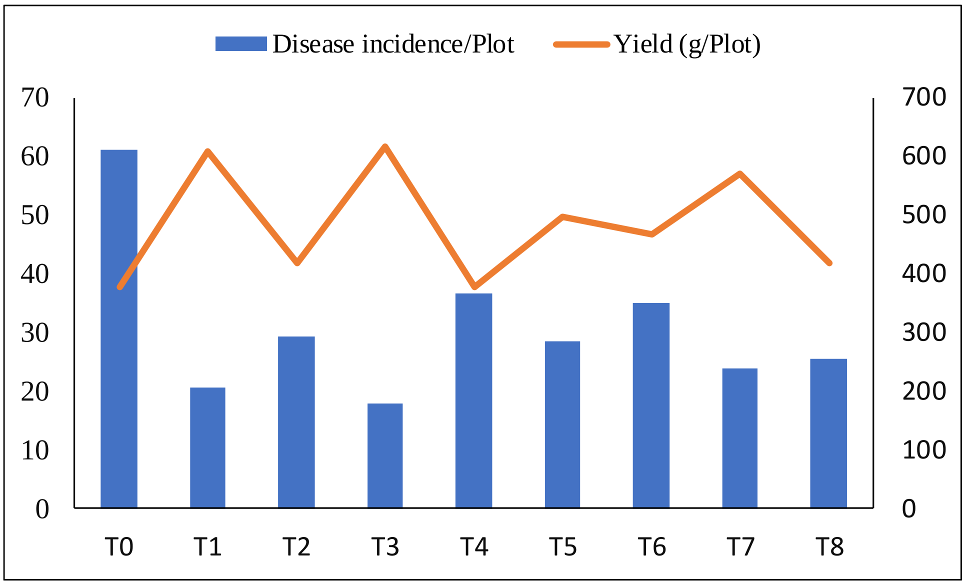



Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 20. Relationship between Percent Disease Index and Chlorophyll content (µg $g^{-1}$) in diseased samples**

## 4.10. Relationship between disease incidence (%) per plot and yield (g plot$^{-1}$)

According to the current study, an inverse relationship was revealed between per plot disease incidence (%) and yield (g plot$^{-1}$). It was found that higher disease incidence (%) was observed with lower quantity of yield (g plot$^{-1}$) and lower disease incidence (%) was observed with higher quantity of yield (g plot$^{-1}$). The maximum per plot disease incidence (61.10 %) was recorded in control treatment that showed the minimum quantity of yield (376.27 g plot$^{-1}$). The minimum per plot disease incidence (17.91%) was recorded when maize was used as a barrier crop that showed maximum quantity of yield (615.32 g plot$^{-1}$).

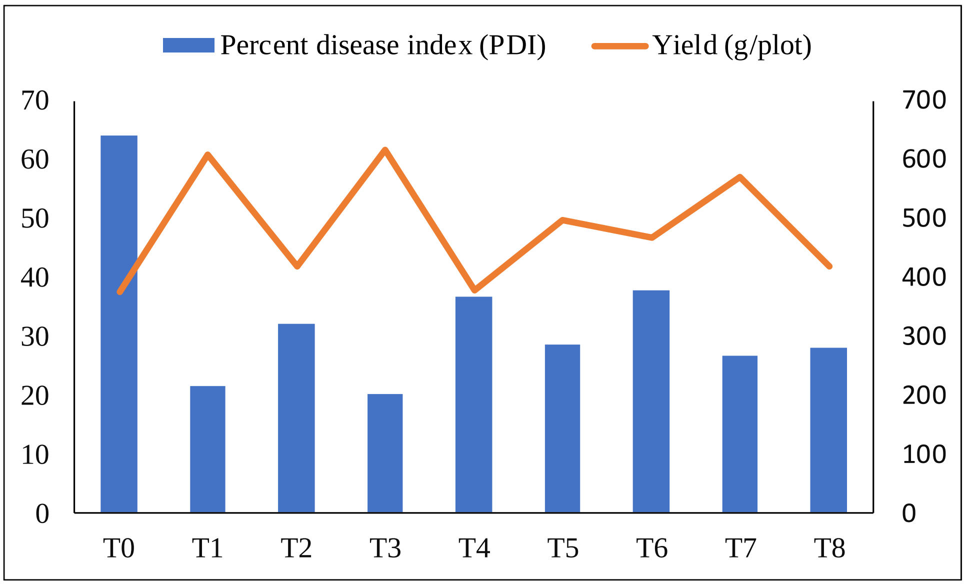



Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 21. Relationship between disease incidence (%) plot$^{-1}$ and yield (g plot$^{-1}$)**

### 4.11. Relationship between percent disease index and yield (g plot$^{-1}$)

The current study showed that there was an inverse relationship between percent disease index and yield (g plot$^{-1}$). It was found that higher percent disease index was observed with lower quantity of yield (g plot$^{-1}$) and lower percent disease index was observed with higher quantity of yield (g plot$^{-1}$). The maximum percent disease index (64.08 %) was recorded in control treatment that showed the minimum quantity of yield (376.27 g plot$^{-1}$). The minimum percent disease index (20.16 %) was recorded when maize was used as a barrier crop that showed that showed maximum quantity of yield (615.32 g plot$^{-1}$).




Here, $T_0$=Control, $T_1$=Sesame, $T_2$=Linseed, $T_3$=Maize, $T_4$=Coriander, $T_5$=Red plastic mulch, $T_6$=Blue Plastic mulch, $T_7$=Silvery-grey plastic mulch, $T_8$=Black plastic mulch

**Figure 22. Relationship between Percent Disease Index (%) plot$^{-1}$ and yield (g plot$^{-1}$)**

# DISCUSSION

Pulses are the most important protein in the diet of the majority of the people in the world including Bangladesh. It contains about twice as much protein as cereals. Moreover, it includes lysine, an amino acid that is typically lacking in cereals (Elias, 1986). Pulse bran is also used as quality feed for animals. Apart from these, the ability to fix nitrogen and addition of organic matter to the soil are important factors in maintaining soil fertility (Senanayake *et al*., 1987; Zapata *et al*., 1987). Mungbean (*Vigna radiata*) is one of the most important pulse crops in Bangladesh in both area and production. In addition to adding organic matter to the soil, it produces grain for human use and helps plants fix nitrogen. There are several causes of low mungbean production, but one obvious is yield losses caused by an insect pest complex. Several insect pest species prey on mungbean. Based on their outward manifestation in relation to the phonological of the mungbean plant, insect pests that attack mungbean may be categorized (Shad *et al*., 2005, Gill *et al*., 1999). They are pests that munch on stems, leaves, pods, and storage materials. Several infections impact the mungbean crop, with *Mungbean yellow mosaic virus* (*MYMV*) being the most significant and pervasive. Older leaves with *MYMV* have erratic yellow and green spots, which result in fully yellowing leaves. Less flowers, pods, and seeds are produced by affected plants. Whitefly population dynamics and their effects on the incidence of the *Mungbean yellow mosaic virus* (*MYMV*) and yield were observed by Islam *et al*. (2008) under the existing environmental circumstances. The prime aim of this study was to manage the *Mungbean yellow mosaic virus* (*MYMV*) using barrier crops and colored plastic mulch.

The disease incidence of *Mungbean yellow mosaic virus* (*MYMV*) was estimated based on different treatments like barrier crops and colored plastic mulches. In case of barrier crops, plot wise minimum disease incidence was recorded when maize was used as barrier crop and in case of colored plastic mulch minimum disease incidence was recorded when silver colored mulch was used. The maximum per plot disease incidence was found in controlled condition. In case of plant wise disease incidence, minimum disease incidence was recorded when maize was used as a barrier crop and in case of colored plastic mulches minimum disease incidence was recorded when silvery-grey colored mulch was used. The maximum per plant disease incidence was found in controlled condition. Similarly, in case of percent disease index, minimum percent disease index was recorded when maize was used as a barrier crop and in case of mulch materials minimum percent disease index were recorded when silvery-grey colored mulch was used. The maximum percent disease index was found in control treatment. Almost similar findings were reported in the previous works done by Kumar and Prasad (2020) in mungbean when they used maize as a barrier crop. The result also agreed with the findings of Patel *et al*., (2021) when they used silver plastic mulch in tomato crop.

The maximum plant height, number of branch per plant, number of flowers per plant, number of healthy leaves per plant, minimum diseased leaves per plant was recorded when maize was used as a barrier crop and silvery-grey colored mulch was used as a mulch material that revealed minimum disease incidence and percent disease index respectively. On the other hand, minimum plant height, number of branch per plant, number of flowers per plant, number of healthy leaves per plant and maximum diseased leaves per plant was recorded in control treatment that revealed maximum disease incidence and percent disease index. The result of the present study agreed with the previous study conducted by Swathi *et al*., (2019) in blackgram when they used maize as a barrier crop and Yuliadhi *et al*., (2017) when they used silver plastic mulch in chilli.

From the study it was revealed that the minimum chlorophyll content in healthy samples as well as in diseased samples were recorded in control treatment and the maximum chlorophyll content in healthy samples as well as in diseased samples were recorded when maize was used as a barrier crop and silvery-grey colored mulch was used as a mulch material which was closely related to disease incidence and percent disease index. Maximum disease incidence and percent disease index was found in control treatment that showed minimum chlorophyll content and minimum disease incidence and severity was found when maize was used as a barrier crop and silvery-grey colored mulch was used as a mulch material that showed the maximum chlorophyll content. Findings were in agreement with Singh and Mall's reports (1973) Similar findings are also reported by Dhillon et al. (1976), who noted a decrease in the amount of chlorophyll in *Calendula officinalis* leaves that had been infected with potato yellow dwarf disease.

The present experimental study revealed that treatments had tremendous effect in 1000-seed weight. The range of 1000-seed weight under different treatments varied notably. The highest weight of 1000 seeds was recorded when maize was used as a barrier crop. In case of mulch materials, silvery-grey plastic mulch gave better performance than others. Almost similar result was found by Swathi *et al*., (2019).

The present study revealed that yield was related to disease incidence and percent disease index. There was an inverse relationship between yield with disease incidence and percent disease index. Minimum yield was found with increased disease incidence and percent disease index. On the other hand, maximum yield was found with decreased disease incidence and percent disease index. Minimum yield was recorded in control treatment that showed maximum disease incidence and percent disease index. Maximum yield was recorded when maize was used as a barrier crop and silvery-grey colored mulch was used as a mulch material that showed minimum disease incidence and percent disease index. It became quite evident that yield reduction was due to the disease infection of *Mungbean yellow mosaic virus.* Rajasri *et al*., (2009) also found almost similar result when they used maize as a guard crop in tomato. In case of plastic mulch Mutetwa and Mtaita (2014) found substantially identical outcomes when they used silvery-grey colored mulch in cucumber.

# CHAPTER V

# SUMMARY AND CONCLUSION

The present study was conducted in the field alloted for the Department of Plant Pathology at Sher-e-Bangla Agricultural University, Dhaka during Kharif-I season. The purpose of the study was to determine how a barrier crops and light-reflecting mulch affect the disease incidence and percent disease index (PDI) of *Mungbean yellow mosaic virus* (*MYMV)* through controlling the insect vector, whitefly. This study included the physiological characteristics of the mungbean plant that alter as a result of the disease intensity that cause serious damages to mungbean production. A single mungbean variety, BINAmoog-5, was cultivated in the field of the SAU farm following standard agronomic practices. The experimental plot was laid out using Randomized Complete Block Design (RCBD) with three (3) replications and nine (9) treatments. The set of treatments were quantified as different treatments included $T_0$ (Control), $T_1$ (Sesame), $T_2$ (Linseed), $T_3$ (Maize), $T_4$ (Coriander), $T_5$ (Red plastic mulch), $T_6$ (Blue plastic mulch), $T_7$ (Silvery-grey plastic mulch), $T_8$ (Black plastic mulch).

From the study it has been found that, the highest per plot disease incidence (25.92%, 35.52% and 61.10% at 30, 45 and 60 DAS respectively) and per plant disease incidence (27.66%, 34.15% and 59.72% at 30, 45 and 60 DAS respectively) was recorded in control treatment. The lowest per plot disease incidence (5.35%, 8.95% and 17.91% at 30, 45 and 60 DAS respectively) and per plant disease incidence (5.24%, 11.75% and 19.09% at 30, 45 and 60 DAS) was found when maize was used as a barrier crop. In case of colored plastic mulch the lowest per plot disease incidence (8.56%, 14.35% and 23.91%) and per plant disease incidence (8.23%, 15.76% and 24.70%) was recorded when silvery-grey colored light reflecting mulch was used. The highest percent disease index (28.14%, 37.71% and 64.08% at 30, 45 and 60 DAS respectively) was found in control treatment and the lowest percent disease index (5.55%, 13.39% and 20.16% at 30, 45 and 60 DAS) was found when maize was used as a barrier crop. In case of colored plastic mulch the lowest percent disease index (7.42%, 17.97% and 26.70%) was found when silvery-grey colored plastic mulch was used.

It has also been found that the amount of chlorophyll content of healthy and diseased samples was negatively correlated with the disease incidence and percent disease index. Therefore, increased disease incidence and percent disease index caused lower amount of chlorophyll content and decreased disease incidence and percent disease index caused higher amount of chlorophyll content. The highest chlorophyll content was recorded when maize was used as a barrier crop and lowest was recorded in control treatment. On the other hand, the yield of mungbean was positively correlated with the chlorophyll concentration. As a result, with the increasing disease incidence low chlorophyll content was found per plot and plant wise, whereas the maximum yield was found with high chlorophyll content.

Based on the results of this study, it can be concluded that the use of barrier crops and plastic mulch showed satisfactory performance in the eco-friendly management of *Mungbean yellow mosaic virus* (*MYMV*) and contributing yield and yield related qualities. Therefore, it may be advised to the farmer to use maize as a barrier crop and silvery-grey colored plastic mulch as a mulch material to manage *MYMV* through controlling the insect vector, whitefly. However, further studies need to be carried out for a consecutive years including more options as management practices in different Agro-ecological zones (AEZs) of the country.

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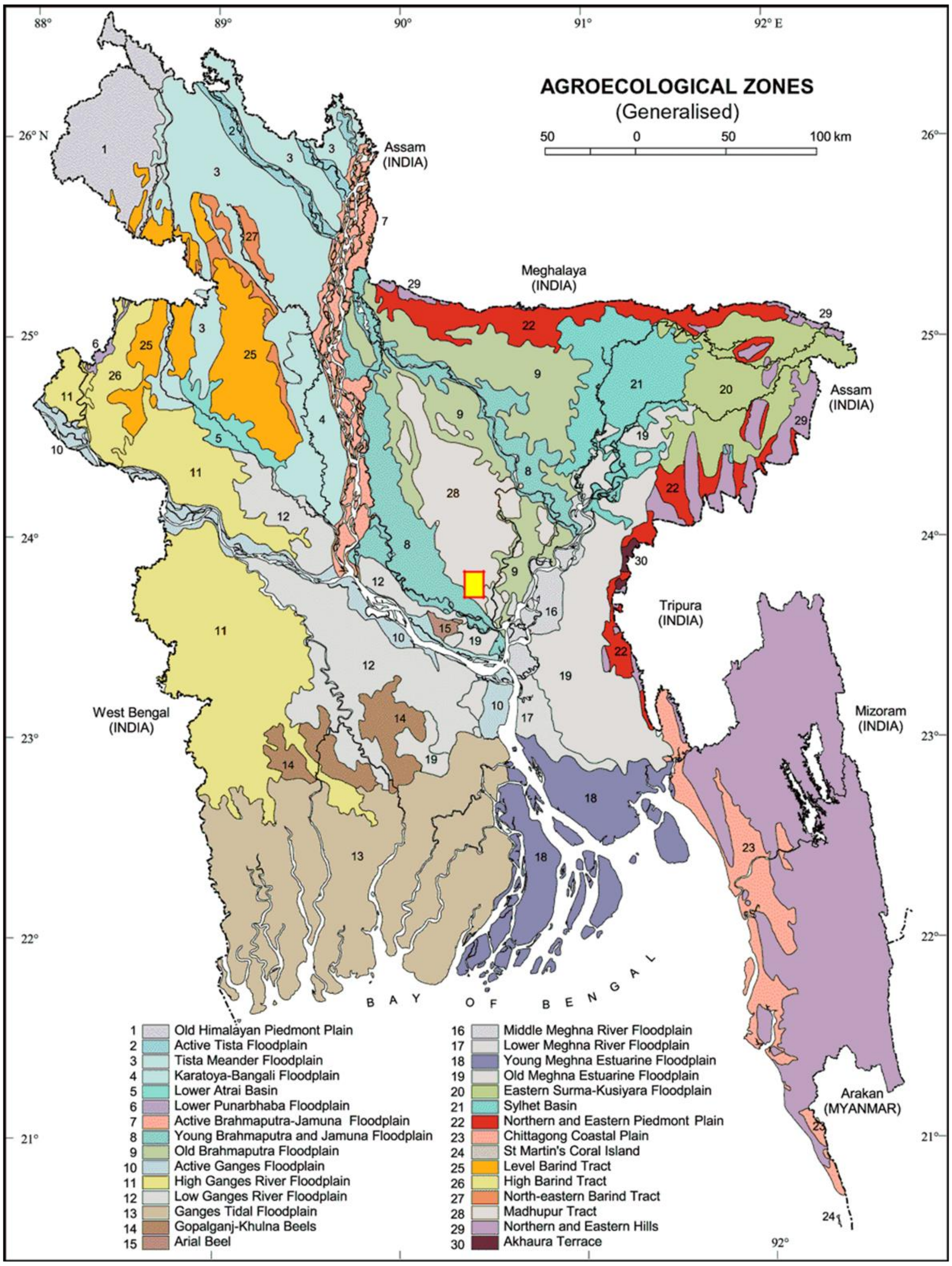
# APPENDIX

## Appendix I. Map showing the experimental site under study



**Appendix-II: Particulars of the Agro-ecological Zone of the Experimental Site.**

Agro-ecological region : Madhupur Tract (AEZ-28)

Land Type : Medium high land

General soil type : Non- Calcareous Dark gray floodplain soil

Soil series : Tejgaon

Topography : Up land

Location : SAU Farm, Dhaka

Field level : Above flood level

Drainage : Fairly good

Firmness (consistency) : Compact to friable when dry

**Appendix III. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from March to June, 2021**

| Month (2021) | * Air temperature°C | | * Relative humidity (%) | * Rainfall (mm) (total) |
|---|---|---|---|---|
| | Maximum | Minimum | | |
| March | 31.7 | 20.5 | 65 | 25 |
| April | 33.4 | 23.2 | 67 | 78 |
| May | 34.7 | 25.9 | 70 | 185 |
| June | 35.4 | 24.9 | 80 | 277 |

* Monthly average

Source: Bangladesh Meteorological Department (Climate and weather division) Agargaon, Dhaka-1207.

**Appendix IV. A view of seed sowing**

**Appendix V. A view of mulching (a. Red plastic mulch, b. Black plastic mulch)**

a

b

**Appendix VI. Photos of barrier crops (a. Sesame, b. Maize)**

**a**

**b**

**Appendix VII. A view of tagging**

## Appendix VIII. Photos of data collection from field