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On

Morphological study of some brinjal lines against shoot and fruit borer (*Leucinodes orbonalis* Guenee)

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Morphological study of some brinjal lines against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee)[1]

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ABSTRACT

Brinjal or eggplant is widely grown vegetable in South and South-East Asian countries. The tropical vegetable, brinjal is cultivated throughout the year in Bangladesh. There are various factors that limits the production of brinjal among which brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) is the most common one which occurs during the time at all the phases of the crop development. This review paper investigated the effects of different morphological characteristics of the plants affecting the brinjal shoot and fruit borer infestation (BSFB) and find some superior resistant lines. Results from various papers found that shoot infestation ranged from 1.11% to 15.86%, and fruit infestation from 18.32% to 61.97% occur. Among the biophysical traits, the Correlation studies showed that percent fruit infestation had a significant positive correlation with plant height, fruit diameter, fruit weight, days to first flowering and days to first fruiting; whereas primary branches per plant, number of fruits per plant, fruit length, number of leaves per plant and leaf trichomes density showed significant negative correlation with the abundance of shoot and fruit borer. After the grading of twenty-eight brinjal lines, G1, G3, G9, G14, G15, G18, G19, G23, G24 and G28 were placed in the moderately tolerant grade based on the lowest fruit and shoot infestation.

Keywords: Growth stage, infestation, susceptible, tolerant.

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LIST OF ABBREVIATIONS

Abbreviations	Explanations
ANOVA	Analysis of variance
BBS	Bangladesh Bureau of Statistics
BSFB	Brinjal Shoot and Fruit Borer
cm	Centimeter
DAT	Days after transplanting
et al.	And others (*at elli*)
FAO	Food and Agriculture Organization
g	Gram
kg	Kilogram
mg	Milligram
mm	Millimetre
RCBD	Randomized complete block design

CHAPTER 1

INTRODUCTION

Vegetables are a good source of various minerals, vitamins, and dietary fibers, along with important phytochemicals which play a major role in our balance diets and nutrition. Each vegetable contains a particular amount of various nutrients element strongly linked with the protection from different diseases of human health (Naeem & Ugur, 2019). Bangladesh is primarily an agricultural country in South Asia, and due to its exclusive fertile land and favorable weather condition, varieties of crops, including vegetables, grow amply in this country. Agriculture, the largest single sector of the economy, contributes about 13.02 % to the country`s Gross Domestic Product (GDP) and employs around 40.60 % of the total labor force in Bangladesh (BBS, 2021).

Brinjal (*Solanum melongena L.*) is one of the most popular vegetables grown extensively by farmers in the kitchen and commercially in both Rabi and Kharif seasons in Bangladesh. It belongs to the family Solanaceae and is an economically important vegetable crop which is consumed throughout the year. In Bangladesh, over 53,664 hectares of cultivable vegetable land is devoted to brinjal cultivation which is about 11.81% of total vegetable cultivation land, with the production of 587212.03 tons during the year 2020-2021 (BBS, 2021). Brinjal accounted for 9.01 and 8.71%, respectively, of all winter and summer vegetable production in 2020 (BBS, 2021). Brinjal production ranks third among all vegetables in the world. It is the second most important vegetable in Bangladesh in terms of both production area and yield, only surpassed by potatoes (Rahman *et al.,* 2016).

Brinjal is a highly nutritious vegetable that is also used for medicinal purposes due to its unique composition. It has very low calories, good minerals like potassium, calcium, magnesium, sodium, iron, and phytochemicals, and dietary fiber that is good for human health (Bhasker & Ramesh Kumar, 2015; Quamruzzaman *et al.,* 2020). Apart from these, brinjal is considered a good source of ascorbic acid and phenolics, both of which are very important antioxidants (Naeem & Ugur, 2019). According to FAO (2015), the optimum daily requirement of vegetables for a full-grown person is 250 g/day, but the consumption is only 56 g/day in Bangladesh. As a

result, chronic malnutrition is widespread in this country. Vegetable production in summer is sparse and in this case,brinjal can play an important role in bridging this lean period.

Several biotic and abiotic factors contribute to lowering the yield in brinjal. Among various biotic factors, insect pests are one of the most important factors which significantly affect the quality and productivity of brinjal crops by inflicting direct damage (Raina & Yadav, 2018). It has been reported that brinjal is attacked by 53 species of insect pests, of which eight are considered major pests which cause enormous damage to the crop in every season in every year (Chakraborti & Sarkar, 2011). Among them, brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee is considered to be the key pest, and it has become the most important production constraint in brinjal growing countries. The damage by this insect starts soon after the transplanting of the seedlings and continues till the harvest of fruits (Nishad *et al.,* 2019).

The main problem in evolving a suitable control measure against this pest is that it belongs to one of the most serious categories of insect pest internal feeders (Mathur *et al.,* 2012). As a result, management practices of the pest are limited to frequent spraying of different chemical insecticides (Das & Islam, 2014; Shubham *et al.,* 2017). Brinjal also happens to be the most sprayed crop. But ineffective pesticides, inaccurate timing of application, and improper doses have resulted in high pesticide costs with little or no appreciable reduction in target pest populations (Islam, 2014). Repeated use of broad spectrum synthetic chemicals for controlling *L. orbonalis* results in environmental contamination, bioaccumulation and bio-magnification of toxic residues, insecticide resistance, secondary pest outbreak, killing of non-target organisms and disturbance in ecological balance (Bhushan *et al.,* 2011; Shubham *et al.,* 2017).

It is, therefore, a national demand to develop alternative approaches to control the pest. Cultural practices, including crop hygiene (crop rotation, ploughing, removing crop residues, and planting time), use of resistant varieties etc. are different ways to manage the pest efficiently. It's been reported that morphological characteristics of host plants inhibit the growth and development of brinjal shoot and fruit borer (Khorsheduzzaman *et al*., 2010; Prabhu *et al.,* 2009; Patil & Hole, 2020; Saikia *et al*., 2021). The morphological properties of host plants and fruits correlate with attraction, oviposition and ingestion of insect pests. The recognition of morphological characteristics of comparatively insect resistant varieties may lead to the introduction of resistance character to favoured genotypes (Shubham *et al.,* 2017). Understanding different

morphological resistance components is essential for the development of strategies to breed resistance to insect pests.

With the above considerations in mind, the present review aimed to:

1. To study different morphological traits of some brinjal lines/treatments.
2. To acquainted the effect of morphological traits of some brinjal lines on the infestation level of the brinjal shoot and fruit borer (BSFB), and
3. To familiar with some brinjal lines which are resistant against brinjal shoot and fruit borer.

CHAPTER 2

MATERIALS AND METHODS

This paper is entirely a review paper. So, this paper is mainly based on secondary information. Different published reports, thesis and articles are used to prepare this paper. Information has been assembled from various articles published in the various books, journals, proceedings and websites available on the online platform.

Good suggestions, valuable information and kind consideration were taken from honorable seminar course instructors, major professor and other resource personnel to enrich this paper. After collecting all the available information, it has been compiled and arranged chronologically as per the objectives of this paper.

CHAPTER 3

REVIEW OF FINDINGS

Brinjal, *Solanum melongena* L. internationally referred to as eggplant (England) or aubergine (France) is a warm-weather crop mostly cultivated in tropical and subtropical regions of the world. According to FAO (2014), it is a versatile and economically important vegetable among small-scale farmers and low income consumers of the entire universe. Brinjal is the second most important vegetable in Bangladesh in terms of both production area and yield, only surpassed by potatoes (Rahman *et al*., 2016). Brinjal occupies about 8.71% of summer vegetables and 9.01% of winter vegetables grown in Bangladesh during 2020-2021(BBS, 2021).

Brinjal is a berry-producing vegetable belonging to the family Solanaceae, which contains approximately 3,000 species distributed in 90 genera (Vorontsova & Knapp, 2012). Brinjal is the fifth most economically important solanaceous crop grown worldwide reported by FAO (2014).

The cultivated brinjal is presumed to be of Indian origin, with China as a secondary center of origin. (Bhaskar & Ramesh Kumar, 2015; Parida *et al.,* 2020; Saikia *et al.,* 2021). It has a huge economic impact in Africa, Europe, and especially in Asia, which produce more than 90% of the total production (Martínez *et al.,* 2021). According to Frary *et al.* (2007), the top five brinjal producing countries are China (57% of the world's total), India (27% of the world's total), Egypt, Turkey, and Iran. It is also a popular vegetable in Egypt, France, Italy, and the United States (Shubham *et al.,* 2021).

3.1 Morphology of brinjal plant

Brinjal plant is an herbaceous with erect or semi spreading habits. It is a perennial plant but cultivated as annual. It develops into bushy plants with large, fuzzy leaves that grow to a height of about 60 to 120 centimeters. The plant has a rather fibrous or lignified root system. The leaves of brinjal are large, simple, lobed and alternate on the stem. The stems, leaves, and calyx of some cultivars are spined. Self-pollination is more common in brinjal than cross pollination. The inflorescence is often solitary, but sometimes it constitutes a cluster of 2 - 5 flowers. The fruit of brinjal is a fleshy berry and forms in a pendant position. It is held by the calyx, which after the corolla has withered, enlarges considerably, enclosing the entire basal portion of the mature fruit. The fruit is usually borne singly at the nodes. The fruits of different varieties of brinjal may extremely variable in shape (oval to oblong) and colour (purple, purple-black, white, green and

red). The seeds are found scattered through the fruit, embedded in a firm placenta (Lawande & Chavan, 1998).

3.2 Insect pests of brinjal

There are several constraints in brinjal cultivation, which are responsible for the reduction in yield and insect pests are one of the most important factors among them. Shubham *et al.* (2021) reported that eggplant is damaged by one hundred forty (140) species of insect pests at different stages of development. Insect- pests infesting brinjal include brinjal shoot and fruit borer (*Leucinodes orbonalis*), whitefly (*Bemisia tabaci*), aphids (*Aphis gossypi*), jassid (*Amrasca biguttula*), Epilachna beetle (*Henosepilacha vigintioctopunctata*), red spider mite (*Tetranychus macfurlanei*) are found to be abundant on this crop (Anjana & Mehta, 2008). According to Choudhary *et al.* (2018), among the insect pests, shoot and fruit borer, *Leucinodes orbonalis* is a major constraint in achieving potential yield.

3.3 Origin and distribution of brinjal shoot and fruit borer

According to Dhaliwa and Aggarwal (2021) distribution of BSFB is mostly higher in areas with hot and humid climates. BSFB is the most damaging pest in south Asia, as reported by Thapa (2010). In Asia, it is the primarily positioned insect of India, Pakistan, Srilanka, Nepal, Bangladesh, Thailand, Philippines, Cambodia, Laos, and Vietnam (Shaukat *et al.*, 2018) and is also reported as the most critical pest in Thailand, China, Taiwan, Japan, Malaysia, Singapore, Brunei, Philippines, and Indonesia (Mainali, 2014; Mally *et al.*, 2015). It is also intercepted from fruit imports in the U.S.A. Netherlands, Denmark, and Great Britain (Mally *et al.*, 2015).

3.5 Behavior of brinjal shoot and fruit borer in relation to plant characteristics

3.5.1 Morphological characteristics

3.5.1.1 Plant

The morphological characteristics of brinjal plant are associated with attraction, feeding and oviposition by BSFB (Bindu & Pramanik, 2017). Shubham *et al.* (2017) reported that the plant height and number of primary branches per plant had a highly significant negative correlation with shoot borer infestation and fruit borer infestation by weight, while Devi *et al.* (2016) found a positive relationship between number of the shoot and per cent shoot infestation. Javed *et al.* (2011) also found a positive and non-significant correlation between number of primary branches

per plant and infestation of BSFB. Javed *et al.* (2011) reported that the stem diameter has a strong and positive correlation with shoot infestation by BSFB. Wagh *et al.* (2012) conducted an experiment with twenty brinjal genotypes at Mahatma Phule Krishi Vidhyapeeth, Rahuri to see the effect of biophysical characteristics of plants on the infestation of shoot and fruit borer on different brinjal genotypes and observed that shoot thickness showed a strong and positive correlation with the incidence of shoot borer and reported that plant with narrow shoot thickness (0.27 to 0.33 cm) showed less shoot damage.

Genotypes having thick shoots provide more space for the movement of larvae and the larvae show enhanced growth and development therefore, the thick shoots are vulnerable to the arrack of shoot borer. An attempt was made by Niranjana *et al.* (2016) to investigate the correlation between various morphological characteristics of plant genotypes with per cent fruit infestation of brinjal shoot and fruit borer. They suggested that the plants with better spread, and more stature were less vulnerable to *L. orbonalis* compare to those with less spread and dwarf structure.

3.5.1.2 Leaf and flower characteristics

Morphological traits of the leaf such as trichomes density, and spines in the leaf can act as a physical barrier to arthropod pest attachment, feeding and oviposition (Mitchell *et al.,* 2016). According to Shubham *et al.* (2017) trichomes play a vital role in imparting resistance in plants to the pest, as long and dense trichomes inhibit the female moth from oviposition and the neonate larvae to reach towards the normal boring site. Similar findings were reported by Shubham *et al.* (2017) and who observed that the trichome act as a barrier for newly hatched larvae to reach the boring site. Khatun *et al.* (2011) and Niranjana *et al.* (2016) reported that resistant varieties had a large number of hairs on the lower surface of the leaf.

Javed *et al.* (2011) reported that the trichomes and hairs on different parts of the plant seem to have a significant role towards a non-preference for fruit infestation by brinjal shoot and fruit borer (*Leucinodes orbonalis*). Less number of leaf trichomes may be responsible for the susceptibility of the brinjal plant to shoot and fruit borer. Challa *et al.* (2021); Devi *et al.* (2016), and Wagh *et al.* (2012) also reported that maximum trichome density was found in less susceptible genotypes of brinjal and trichome density had a significant negative correlation with percent shoot infestation and fruit infestation.

3.5.1.3 Fruit characteristics

Amin *et al.* (2014) found a negative correlation between the number of fruit per plant and percent fruit infestation by BSFB. Shubham *et al.* (2017) reported that the number of fruits per plant showed a highly significant positive correlation with fruit yield per plant and there was a significant negative correlation between yield per plant and per cent fruit borer infestation on weight basis. The genotypes with fruits having long pedicel and calyx were more susceptible than those with short pedicel and calyx (Devi *et al.*, 2016).

Calyx is the most important morphological component which has a strong association with pest infestation. Amin *et al.* (2014) observed that the highly susceptible genotype has maximum length of calyx; however, short calyx length was observed in less susceptible genotypes as the length of calyx exhibited a highly significant and positive correlation in relation to percent infestation by *L. orbonalis*. The long and big or loose calyx in the highly susceptible genotypes might help the young borer to hide and get easily into the fruit through the soft tissue below the calyx. Oval, thin and elongated fruits of brinjal plants are resistant to brinjal shoot and fruit borer (Patel, 2013).

Patel (2013) and Wagh *et al.* (2012) explained a negative correlation between the length of fruits and degree of fruit infestation by BSFB whereas Niranjana *et al.* (2016) and Shubham *et al.* (2017) did not find any linear correlation between length of fruits and degree of fruit infestation. Correlation between the length of fruit and the level of fruit infestation was found negative by Amin *et al.* (2014). Shubham *et al.* (2017) reported that fruit diameter had a non- significant positive correlation with percent fruit borer infestation by weight. Similarly, Amin *et al.* (2014) found a positive correlation between fruit diameter and fruit infestation by BSFB.

Nagappan and Vethamoni (2016) reported that the green fruit colour of brinjal was associated with resistance to *L. orbonalis*, while the purple fruit colour was associated with susceptibility to this insect. Less susceptibility of the green fruited genotype of brinjal to BFSB was reported by Amin *et al.* (2014); Dar *et al.* (2014); Jat and Parrek (2003) and Prasad *et al.* (2014). Wagh *et al.* (2012) observed that green color fruits were significantly less susceptible and violet color (pink) fruits were highly susceptible followed by light green color fruit.

3.6 Incidence of BSFB at the different growth stages of the brinjal lines

3.6.1 Shoot infestation

The percent shoot infestation by brinjal shoot and fruit borer (BSFB) reviewed in 28 mutant lines of brinjal at vegetative, early fruiting, mid fruiting, and late fruiting stages was statistically significant (Table 1). In case of the vegetative stage of brinjal, the highest shoot infestation (12.96 %) among the 28 mutant lines was recorded in G17, which was statistically different from all other lines, followed by G6, G5, G8, G13, G2, G27, and G21 those contributed 10.18%, 9.26%, 8.79%, 6.48%, 5.59% 4.63% and 1.39% shoot infestation, respectively. On the other hand, no shoot infestation was recorded in the rest of the lines at the vegetative stage. In the early fruiting stage, the highest shoot infestation (24.91%) was recorded in G4 on the other hand the lowest shoot infestation (0.50%) at the early fruiting stage was recorded in G9, which was statistically similar to G8, G5, G6, G28, G24, and G1, which contributed 2.54%, 2.08%, 1.70%, 1.38%, 1.11%, and 0.79% shoot infestation, respectively. In all lines, the shoot infestation was lower in the early stage and increased gradually with the increase of plant ages up to the mid-fruiting stage. So, the order of shoot infestation for all of the brinjal lines is mid-fruiting stage > late fruiting stage > early fruiting stage > vegetative stage. The level of shoot infestation by BSFB found in the present investigation has similarities to the findings of Mannan *et al.* (2015); Naik *et al.* (2008), and Sultana *et al.* (2018). They said that BSFB infestation varied significantly in relation to plant age and season.

From the result presented in Table 2, none of the twenty-eight brinjal mutant lines tested, was resistant to shoot infestation caused by brinjal shoot and fruit borer. Two mutant lines *viz.* G9 and G24 were tolerant to shoot infestation, recording overall mean fruit infestation of less than 2.0 percent. The moderately tolerant comprised one mutant line i.e. G1, which falls in between 2.1 and 3.0 percent shoot infestation. The highly susceptible (above 5%) reaction was found in twenty-two brinjal mutant lines *viz.* G2, G3, G4, G5, G6, G7, G8, G10, G11, G12, G13, G14, G16, G17, G19, G20, G21, G22, G23, G25, G26 and G27. The above findings revealed that G24, G9, and G1 brinjal mutant lines are the most suitable brinjal mutants in terms of tolerance to shoot infestation against BSFB.

Table 1. Shoot infestation caused by brinjal shoot and fruit borer in twenty-eight brinjal lines at different stage

Treatments/ Lines	% Shoot infestation at different fruiting stages of plant				
	Vegetative (30-60 DAT)	**Early (61-90 DAT)**	**Mid (91-120 DAT)**	**Late (121-150 DAT)**	**Mean % infestation**
G1	0.00 h	0.79 j	3.35 p	9.04 cd	3.30 lm
G2	5.59 e	10.07 ef	25.37 d-f	14.44 a	13.86 ab
G3	0.00 h	15.31 c	22.69 fg	5.46 ij	10.86 d-f
G4	0.00 h	24.91 a	17.96 h-j	10.68 b	13.39 a-d
G5	9.26 c	2.08 j	6.87 no	8.836 c-e	6.76 i-k
G6	10.18 b	1.70 j	10.27 lm	9.55 bc	7.92 g-i
G7	0.00 h	7.75 h	12.92 k-m	7.72 e-g	7.10 h-k
G8	8.79 c	2.54 j	9.62 mn	9.78 bc	7.68 g-j
G9	0.00 h	0.50 j	3.60 op	1.04 m	1.28 m
G10	0.00 h	5.40 i	19.05 h	8.07 d-g	8.13 g-i
G11	0.00 h	9.20 f-h	18.31 hi	4.89 i-k	8.10 g-i
G12	0.00 h	4.86 i	15.56 i-k	5.79 hi	6.55 i-k
G13	6.48 d	12.28 d	19.46 gh	5.80 hi	11.00 c-f
G14	0.00 h	16.38 bc	30.50 c	3.16 lm	12.51 b-e
G15	0.00 h	4.89 i	14.68 jk	0.00 n	4.89 kl
G16	0.00 h	9.49 f-h	24.36 ef	7.00 gh	10.20 e-g
G17	12.96 a	9.49 f-h	28.47 cd	0.00 n	12.73 b-e
G18	0.00 h	4.68 i	15.13 i-k	0.55 n	5.00 j-l
G19	0.00 h	11.25 d-f	34.97 b	8.30 d-f	13.63 a-c
G20	0.00 h	17.11 bc	40.41 a	5.91 hi	15.86 a
G21	1.39 g	15.66 bc	24.98 ef	4.84 i-l	11.71 b-f
G22	0.00 h	12.43 d	23.14 ef	5.26 ij	10.21 e-g
G23	0.00 h	12.07 de	25.00 ef	7.48 fg	11.13 c-f
G24	0.00 h	1.11 j	3.33 p	0.00 n	1.11 m
G25	0.00 h	7.83 gh	26.09 de	4.02 k-m	9.48 f-h
G26	0.00 h	9.82 fg	30.50 c	3.64 lm	10.99 c-f
G27	4.63 f	17.50 b	31.13 c	2.85 m	14.03 ab
G28	0.00 h	1.38 j	13.23 kl	4.53 j-l	4.78 kl
CV (%)	**10.52**	**7.26**	**5.27**	**6.77**	**9.30**

[In columns, each mean is the average of three replications, and means followed by the same letter (s) indicate the statistically similar with each other at a 5% level of significance with Tukey's HSD.]

(Source:Pranto,2022)

Table 2. Screening of some brinjal lines against shoot infestation by BSFB

Level of shoot infestation (%)	Brinjal mutant line/ Treatments	Categories	Grade
< 2.0	G9, G24	Tolerant	T
2.1-3.0	G1	Moderately Tolerant	MT
3.1-5.0	G15, G18, G28	Susceptible	S
> 5.0	G2,G3,G4,G5,G6,G7,G8,G10,G11,G12,G13,G14,G16,G17,G19,G20,G21,G22,G23,G25,G26,G27	Highly Susceptible	HS

*Grade formula given by Niranjana *et al.* (2016). (Source:Pranto,2022)

3.6.2 Fruit infestation

The percent fruit infestation by number due to brinjal shoot and fruit borer (BSFB) reviewed in 28 lines of brinjal at early fruiting, mid fruiting, and late fruiting stages was statistically significant (Table 3). In case of early fruiting stage of the plant, the highest fruit infestation by number (52.27%) was recorded in G17, which was statistically similar to G21 (49.20). On the other hand, the lowest fruit infestation by number at early fruiting stage (6.81%) was recorded in G9, which was statistically different from all other lines followed by G25, G24, G1, G28, and G3, those responsible for 9.09%, 10.26%, 11.80%, 12.87% and 14.37% fruit infestation by number, respectively.

It was found that with increasing growth stages of the plant, the percent fruit infestation by number was also increased, the lowest fruit infestation was found at the early fruiting stage for all brinjal lines and the highest fruit infestation at the late fruiting stage. By considering the growth stages of the plants, the order of trends of fruit infestation by number for all of the brinjal lines is late fruiting stage > mid fruiting stage > early fruiting stage. Similar results were also reported by Mannan *et al.* (2015) and Naik *et al.* (2008).

From the result presented in Table 4, among the twenty-eight brinjal lines tested, none of those was resistant or tolerant to fruit infestation caused by brinjal shoot and fruit borer. Ten mutant lines *viz.* G1, G3, G9, G14, G15, G18, G19, G23, G24, and G28 were moderately tolerant, recording overall mean fruit infestation. The susceptible comprised twelve lines *viz.* G5, G6, G8, G11, G12, G13, G16, G20, G22, G25, G26, and G27, while highly susceptible reactions i.e. infestation above 46.00 percent, was exhibited by six brinjal mutant lines *viz.* G2, G4, G7, G10, G17, G21 (Table 4).

Table 3. Fruit infestation by number caused by BSFB in twenty-eight brinjal lines at different stages

Treatments/ Lines	% Fruit infestation by number at different fruiting stages of plant			
	Early (60-90 DAT)	Mid (91-120 DAT)	Late (121-150 DAT)	Mean % infestation
G1	11.80 l-o	21.86 mn	32.05 lm	21.90 o-q
G2	45.00 b	56.39 a	84.52 a	61.97 a
G3	14.37 lm	28.30 i-l	32.46 lm	24.93 no
G4	34.28 cd	48.63 bc	61.11 c	48.00 b-d
G5	26.51 fg	38.05 e-g	47.77 e-h	37.45 gh
G6	25.75 f-h	38.06 e-g	45.130 g-j	36.31 hi
G7	45.00 b	54.25 ab	55.55 cd	51.60 b
G8	26.13 fg	32.02 g-k	36.50 kl	31.55 j-l
G9	6.81 o	18.98 n	29.16 m	18.32 q
G10	45.00 b	41.56 de	51.89 d-f	46.15 c-e
G11	33.03 de	44.97 cd	45.00 g-j	41.00 fg
G12	19.44 jk	34.54 f-i	52.27 de	35.42 h-j
G13	37.50 cd	35.480 e-h	52.77 de	41.95 ef
G14	29.16 ef	29.45 h-k	33.75 lm	30.79 k-m
G15	23.61 g-j	18.57 n	29.02 m	23.73 n-p
G16	38.09 c	52.83 ab	45.83 f-j	45.58 de
G17	52.27 a	49.44 bc	49.20 e-h	50.30 bc
G18	19.53 jk	27.02 k-m	28.61 m	25.05 no
G19	23.33 g-j	28.18 j-l	36.66 kl	29.39 k-m
G20	20.77 h-j	30.42 h-k	47.22 e-i	32.80 i-k
G21	49.20 ab	50.95 a-c	73.33 b	57.83 a
G22	24.74 f-i	27.13 j-m	43.05 h-j	31.64 j-l
G23	15.55 kl	30.35 h-k	36.66 kl	27.52 l-n
G24	10.26 m-o	18.27 n	31.11 lm	19.88 pq
G25	9.09 no	37.32 e-g	50.00 d-g	32.13 i-k
G26	19.87 i-k	33.33 f-j	40.17 jk	31.12 k-m
G27	28.75 ef	38.66 ef	41.42 i-k	36.28 hi
G28	12.87 l-n	23.50 l-n	44.15 g-j	26.84 mn
CV (%)	**5.87**	**5.59**	**4.33**	**3.77**

[In columns, each mean is the average of three replications and means followed by the same letter (s) indicate the statistically similar with each other at 5% level of significance with Tukey's HSD.]

(Source:Pranto,2022)

Table 4. Screening of some brinjal lines against fruit infestation by BSFB

Level of fruit infestation (%)	Brinjal mutant line/treatments	Categories	Grade
1-15	No	Tolerant	T
16-30	G1, G3, G9, G14, G15, G18,G19, G23,G24, G28	Moderately Tolerant	MT
31-45	G5,G6,G8,G11,G12,G13,G16, G20,G22,G25,G26,G27	Susceptible	S
Above 46	G2, G4, G7, G10, G17, G21	Highly Susceptible	HS

*Grade formula is given by Rishi *et al.* (2018). (Source:Pranto,2022)

3.7 Morphological characteristics of brinjal lines influencing the infestation rate of BSFB

3.7.1 Quantitative characteristics of plant

Plant related quantitative characteristics of 28 brinjal lines with the overall mean shoot and fruit infestation by BSFB was reviewed. The results obtained have been depicted in Table 5 and as here below.

3.7.1.1 Plant height (cm)

The maximum plant height (107.57 cm) was recorded in G21 which was statistically similar to G22 (106.72 cm) and G3 (98.58 cm), respectively and significantly different from other lines. The minimum plant height (52.57 cm) was recorded in G8. In case of percent shoot and fruit infestation it was observed that brinjal line G21 with maximum plant height had comparatively high infestation. On the other hand, G8 with minimum plant height had comparatively minimum infestation.

Table 5. Plant character values and shoot and fruit borer infestation of brinjal lines

Treatments / Lines	Plant height (cm)	No. of primary branch/plant	No. of leaves/ plant	Leaf trichomes (density/10 mm2)	Diameter of top internode (mm)	Days to first flowering (DAT)	Days to first fruiting (DAT)	Mean shoot infestation (%)	Mean fruit infestation (%)
G1	70.53 f-h	22.00 a	304.33 a	69.75 bc	3.13 hi	42.00 de	45.00 fg	3.30 lm	21.90 o-q
G2	84.17 de	17.50 c-g	110.00 m	56.25 e-g	5.13 a	51.66 ab	54.66 d	13.86 ab	61.97 a
G3	98.58 a-c	18.50 b-f	117.67 k-m	67.25 cd	4.48 a-e	35.00 j-l	42.00 hi	10.86 d-f	24.93 no
G4	76.63 e-g	13.00 i-k	88.67 n	53.00 f-h	4.64 a-d	54.16 a	59.66 bc	13.39 a-d	48.00 b-d
G5	56.73 i-k	19.66 a-e	171.00 h	50.00 gh	4.84 a-c	48.16 c	61.50 ab	6.76 i-k	37.45 gh
G6	60.55 h-k	20.83 a-c	192.00 fg	51.50 f-h	4.54 a-e	37.67 g-j	45.00 fg	7.92 g-i	36.31 hi
G7	94.37 b-d	12.33 k	115.33 lm	48.50 gh	4.95 ab	49.33 bc	59.50 c	7.10 h-k	51.60 b
G8	52.57 k	18.16 b-f	185.00 g	52.00 f-h	4.51 a-e	37.83 f-i	43.66 gh	7.68 g-j	31.55 j-l
G9	68.72 f-i	19.00 a-f	127.67 j	77.25 b	4.00 d-g	35.00 j-l	38.00 k-m	1.28 m	18.32 q
G10	63.22 h-k	19.00 a-f	192.33 fg	48.25 gh	4.43 b-e	32.66 lm	35.83 no	8.13 g-i	46.15 c-e
G11	65.38 g-j	19.50 a-e	209.33 cd	48.75 gh	4.56 a-e	33.00 k-m	37.50 l-n	8.10 g-i	41.00 fg
G12	88.20 c-e	15.83 f-j	109.33 m	69.00 bc	4.26 c-f	35.00 j-l	41.00 ij	6.55 i-k	35.42 h-j
G13	87.55 c-e	13.50 h-k	95.67 n	61.75 c-e	4.84 a-c	52.83 a	62.50 a	11.00 c-f	41.95 ef
G14	80.47 ef	12.83 jk	117.00 lm	59.75 d-f	4.49 a-e	36.00 h-j	41.17 ij	12.51 b-e	30.79 k-m
G15	58.00 h-k	13.50 h-k	147.67 i	87.00 a	3.63 f-h	38.33 f-h	40.50 ij	4.89 kl	23.73 n-p
G16	58.32 h-k	20.16 a-d	173.67 h	52.25 f-h	4.36 b-e	33.16 k-m	36.16 m-o	10.20 e-g	45.58 de
G17	88.85 c-e	12.16 k	111.33 m	53.00 f-h	4.83 a-c	40.50 ef	43.66 gh	12.73 b-e	50.30 bc
G18	61.43 h-k	16.33 e-i	218.67 bc	67.50 cd	3.43 g-i	44.00 d	47.00 e	5.00 j-l	25.05 no
G19	76.37 e-g	14.33 g-k	123.50 j-l	59.75 d-f	4.48 a-e	37.66 g-j	40.70 ij	13.63 a-c	29.39 k-m
G20	67.42 g-j	21.33 ab	206.33 cd	55.75 e-h	4.55 a-e	35.50 i-k	39.83 jk	15.86 a	32.80 i-k
G21	107.57 a	16.83 d-h	172.67 h	47.50 h	5.01 ab	40.33 e-g	46.00 f	11.71 b-f	57.83 a
G22	106.72 ab	15.83 f-j	150.33 i	54.25 e-h	4.58 a-d	36.33 h-j	45.67 ef	10.21 e-g	31.64 j-l
G23	88.62 c-e	13.83 h-k	129.67 j	61.75 c-e	4.59 a-d	35.16 i-l	39.67 jk	11.13 c-f	27.52 l-n
G24	59.48 h-k	18.66 a-f	228.33 b	68.75 c	2.95 i	28.33 no	38.17 kl	1.11 m	19.88 pq
G25	60.40 h-k	19.16 a-f	203.33 de	53.50 e-h	4.42 b-e	31.00 mn	36.83 l-n	9.48 f-h	32.13 i-k
G26	55.18 jk	19.16 a-f	198.67 ef	50.50 gh	3.90 e-g	32.00 m	34.67 o	10.99 c-f	31.12 k-m
G27	55.47 jk	20.50 a-c	189.67 fg	51.25 gh	4.36 b-e	32.16 m	34.66 o	14.03 ab	36.28 hi
G28	77.62 efg	16.00 f-j	122.00 j-l	56.25 e-g	3.49 g-i	28.00 o	32.50 p	4.78 kl	26.84 mn
CV	**5.32**	**6.26**	**1.97**	**4.47**	**4.80**	**2.29**	**1.42**	**9.30**	**3.77**

[In columns, each mean is the average of three replications, and means followed by the same letter (s) indicate the statistically similar with each other at a 5% level of significance with Tukey's HSD.] (Source:Pranto,2022)

3.7.1.2 Number of primary branch per plant

The highest number of primary branches per plant (22.00) was recorded on G1 followed by G20 (21.33), G6 (20.83), G27 (20.50) and G16 (20.26) respectively while the least number of primary branches of 12.16 per plant was recorded on G17 followed by G7 (12.33), G14 (12.83) and G4 (13.00) respectively. It was reviewed that brinjal line G1 with the highest number of primary branches had comparatively lower shoot (3.30%) and fruit (21.90%) infestation while line G17 with the least number of primary branches had comparatively higher shoot (12.73%) fruit (50.30%) infestation (Table 5).

3.7.1.3 Number of leaves per plant

The maximum number of leaves per plant (304.33) was recorded in G1 brinjal line which is significantly different from other lines followed by G24 (228.33), G18 (218.67), G11 (209.33) and G20 (206.33) respectively while the lowest number of leaves (88.67) was recorded in G4 which was statistically similar with G13 but statistically different from other lines followed by G12 (109.33), G2 (110.00), G17 (111.33) and G7 (115.33) respectively. It was reviewed that brinjal line G1 with the highest number of leaves had comparatively lower infestation while line G4 with the lowest number of leaves had comparatively higher infestation (Table 5).

3.7.1.4 Leaf trichomes density

The highest leaf trichome density (no. /10mm^2) was recorded in G15 (87.00) which was statistically different from those of all other brinjal lines. The lowest number of trichome (47.5) was found in brinjal line G21. It was reviewed that brinjal line G15 with the highest leaf trichomes density had comparatively lower infestation while line G21 with the lowest leaf trichomes density had comparatively higher infestation (Figure 1).

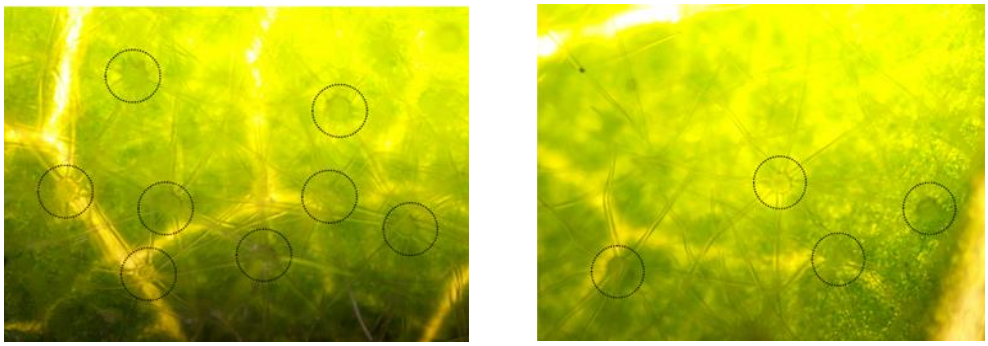

Figure 1: Leaf trichome density comparisons between a tolerant and a susceptible genotype. (Source: Pranto,2022)

3.7.1.5 Diameter of top internode

Brinjal line G2 produced the highest diameter of the top internode (5.13mm) and the lowest diameter was recorded from G24 (2.95 mm). It was reviewed that brinjal line G2 with the highest diameter of the top internode had comparatively higher shoot infestation (13.86%) while G24 with a lower diameter of the top internode had the lowest shoot infestation (1.11%) among the brinjal lines.

3.7.1.6 Days to first flowering and fruiting

Among the brinjal lines minimum days to first flowering was recorded in G28 (28.00 days), while maximum days to first flowering was recorded in G4 (54.16 days). Minimum days to first fruiting was recorded in G28 (32.50 days) and maximum days to first fruiting was recorded in G13 (62.50 days).

3.7.2 Quantitative characteristics of the fruit

Fruit related quantitative characteristics of 28 brinjal lines with overall mean fruit infestation by BSFB was undertaken. The results obtained have been depicted in Table 6 and as here below.

3.7.2.1 Fruit length

The data of fruit length (Table 6) revealed that the brinjal line, G3 recorded the highest fruit length (150.16 mm) and G24 was recorded for the lowest fruit length (38.00 mm).

3.7.2.2 Fruit diameter

Brinjal line, G4 was recorded for the highest fruit diameter (73.58 mm) and lowest fruit diameter (27.69 mm) was recorded in G24. Brinjal line G4 with the highest fruit diameter had comparatively higher fruit infestation (48.00%) while line G24 with the lowest fruit diameter had comparatively lower fruit infestation (19.88%) (Table 6).

3.7.2.3 Fruit weight

Among the twenty-eight brinjal lines, G6 had maximum fruit weight (145.78 g) and minimum fruit weight was recorded in G24 (13.06 g) (Table 6). Comparatively higher fruit infestation (36.31%) was observed in brinjal line G6 with maximum fruit weight, while line G24 with minimum fruit weight had lower fruit infestation.

3.7.2.4 Number of fruits per plant

The maximum number of fruits per plant was recorded in brinjal line G1 (28.33) and the minimum number of fruits per plant was recorded in G2 (8.00). It was found that G1 with a maximum number of fruits per plant had a lower fruit infestation (21.90%) while G2 with a minimum number of fruits per plant had a higher fruit infestation (61.97%).

3.7.2.5 Length of fruit calyx

Brinjal line G22 had the highest (40.55 mm) length of fruit calyx while the lowest length of fruit calyx was recorded in G1 (13.45 mm).

3.7.2.6 Length of fruit pedicel

Brinjal line G3 had the highest (64.84 mm) length of fruit pedicel while the lowest length of fruit pedicel was recorded in G18 (30.96 mm).

Table 6. Fruit character values and brinjal shoot and fruit borer infestation of brinjal lines

Treat ments	Fruit length (mm)	Fruit diameter (mm)	Single fruit weight (g)	No. of fruits per plant	Length of fruit calyx (mm)	Length of fruit pedicel (mm)	Mean fruit infestation (%)
G1	39.95 n	29.42 lm	21.56 k	28.33 a	13.45 j	32.62 jk	21.90 o-q
G2	99.01 f	52.49 gh	112.78 c	8.00 j	30.67 e-h	44.76 c-f	61.97 a
G3	150.16 a	38.15 jk	89.61 fg	18.50 b-d	39.31 ab	64.84 a	24.93 no
G4	64.63 ij	73.58 a	141.17 a	10.68 g-j	28.44 gh	43.09 d-g	48.00 b-d
G5	55.99 k-m	63.95 c-e	94.83 f	13.00 d-j	29.87 e-h	38.10 hi	37.45 gh
G6	62.57 i-k	68.56 a-c	145.78 a	16.33 d-g	31.32 e-g	40.81 f-h	36.31 hi
G7	64.57 ij	69.91 a-c	122.22 b	10.15 h-j	28.55 f-h	45.93 c-e	51.60 b
G8	60.86 i-l	66.44 b-e	112.78 c	11.83 e-j	28.54 gh	39.23 g-i	31.55 j-l
G9	58.69 j-m	50.81 gh	57.33 i	24.00 ab	21.41 i	38.73 g-i	18.32 q
G10	58.24 j-m	64.89 c-e	106.72 de	13.33 d-j	30.05 e-h	41.39 e-h	46.15 c-e
G11	73.95 gh	61.11 ef	109.72 cd	14.83 d-h	31.60 e-g	42.84 d-g	41.00 fg
G12	112.41 e	47.02 hi	114.67 c	9.00 ij	39.06 ab	48.88 c	35.42 h-j
G13	53.80 lm	71.99 ab	109.50 cd	9.66 h-j	32.79 de	41.66 e-h	41.95 ef
G14	122.94 d	35.07 kl	85.33 gh	13.00 d-j	38.00 a-c	48.53 c	30.79 k-m
G15	51.68 m	44.22 ij	43.50 j	16.66 d-f	23.79 i	35.90 ij	23.73 n-p
G16	54.10 lm	64.63 c-e	91.78 f	11.50 f-j	28.91 f-h	39.25 g-i	45.58 de
G17	81.29 g	55.79 fg	93.67 f	10.50 h-j	27.26 h	47.15 cd	50.30 bc
G18	51.52 m	28.23 m	19.50 k	22.83 a-c	21.50 i	30.96 k	25.05 no
G19	125.98 cd	41.91 ij	94.56 f	18.00 cd	35.25 cd	54.79 b	29.39 k-m
G20	56.35 k-m	67.89 a-d	103.50 e	14.86 d-h	30.43 e-h	41.04 f-h	32.80 i-k
G21	66.73 hi	69.29 a-c	90.89 f	8.33 j	31.98 d-f	48.29 c	57.83 a
G22	138.79 b	32.53 k-m	102.17 e	17.33 c-e	40.55 a	49.29 c	31.64 j-l
G23	133.37 bc	30.73 lm	91.94 f	15.16 d-h	36.40 bc	48.13 c	27.52 l-n
G24	38.00 n	27.69 m	13.06 l	27.33 a	13.76 j	31.87 jk	19.88 pq
G25	51.73 m	61.88 d-f	82.50 h	13.33 d-j	30.31 e-h	39.49 g-i	32.13 i-k
G26	51.29 m	64.68 c-e	94.61 f	12.83 d-j	29.01 f-h	40.41 f-i	31.12 k-m
G27	51.87 m	66.34 b-e	92.44 f	14.66 d-i	27.41 h	40.43 f-i	36.28 hi
G28	131.12 c	31.01 lm	103.78 e	12.00 e-j	37.13 a-c	55.50 b	26.84 mn
CV	**3.04**	**3.79**	**6.86**	**12.15**	**3.60**	**3.35**	**3.77**

[In columns, each mean is the average of three replications and means followed by the same letter (s) indicate the statistically similar with each other at 5% level of significance with Tukey's HSD.]

(Source: Pranto,2022)

3.7.1 Qualitative characteristics

Fruit characteristics are considered as important ones for resistant breeding. Considering the qualitative character of fruits of the tested brinjal line *viz.* fruit color, fruit shape fruit curvature and calyx spininess, significant variation was observed among brinjal lines (Table 7). The fruit color of brinjal is considered as one of the important characteristics of consumer preference. Generally, green and purple color brinjal are common in the local market. However, significant variations in fruit color were found in the present study (Figure 2). The percent fruit infestation for all of the brinjal lines based on fruit color is green > dark purple > purple > Greenish purple > white. Previously it was reported that the green fruit colour of brinjal was associated with resistance to *L. orbonalis*, while purple fruit colour was associated with susceptibility to this insect. Less susceptibility of the green fruited genotype of brinjal to BFSB was also reported by Dar *et al.* (2014), Jat and Parrek (2003), Nagappan and Vethamoni (2016), Prasad *et al.* (2014) and Wagh *et al.* (2012). Although results of this study showed that even green fruits like the G2 brinjal line could confer susceptibility to BSFB.

Out of twenty-eight mutant lines had six different types of fruit shapes which showed oval (three), obovate (two), long (six), oblong (one), round (five) and flattened (eleven). Among them, oval shape fruit was the least preferred by fruit borers with an overall mean fruit damage of 22.3%. The percent fruit infestation for all of the brinjal lines based on fruit shape is obovate > round > flattened > oblong > long > oval. Patel (2013) also reported that oval, thin and elongated fruits of brinjal plants are resistant to brinjal shoot and fruit borer. Payal *et al.* (2015) found the highest fruit damage in round fruits.

Among the brinjal lines, only six lines (G3, G14, G19, G22, G23, and G28) had curved fruit. It was observed that fruit with curvature had less infestation compared to the fruit without curvature. However, there were two lines (G9 and G15) among the twenty-eight brinjal lines with spines on the calyx, which showed a negative effect on the percent fruit infestation (Table 7).

Table 7. Qualitative features of fruits effect on per cent infestation of fruit by BSFB

Treatments Lines	Fruit color	Fruit Shape	Fruit curvature	Calyx spininess	Mean % fruit infestation
G1	White	Oval	No	No	21.90 o-q
G2	Green	Obovate	No	No	61.97 a
G3	Purple	Long	Curved	No	24.93 no
G4	Green	Round	No	No	48.00 b-d
G5	Purple	Flattened	No	No	37.45 gh
G6	Purple	Flattened	No	No	36.31 hi
G7	Green	Round	No	No	51.60 b
G8	Purple	Flattened	No	No	31.55 j-l
G9	White	Round	No	Yes	18.32 q
G10	Purple	Flattened	No	No	46.15 c-e
G11	Dark Purple	Flattened	No	No	41.00 fg
G12	Dark Purple	Oblong	No	No	35.42 h-j
G13	White	Flattened	No	No	41.95 ef
G14	Greenish purple	Long	Curved	No	30.79 k-m
G15	White	Round	No	Yes	23.73 n-p
G16	Purple	Flattened	No	No	45.58 de
G17	Green	Obovate	No	No	50.30 bc
G18	White	Oval	No	No	25.05 no
G19	Purple	Long	Curved	No	29.39 k-m
G20	Purple	Flattened	No	No	32.80 i-k
G21	Green	Round	No	No	57.83 a
G22	Greenish purple	Long	Curved	No	31.64 j-l
G23	Greenish purple	Long	Curved	No	27.52 l-n
G24	White	Oval	No	No	19.88 pq
G25	Purple	Flattened	No	No	32.13 i-k
G26	Purple	Flattened	No	No	31.12 k-m
G27	Purple	Flattened	No	No	36.28 hi
G28	Greenish purple	Long	Curved	No	26.84 mn

[In columns, each mean is the average of three replications and means followed by the same letter (s) indicate the statistically similar with each other at 5% level of significance with Tukey's HSD.]

(Source:Pranto,2022)

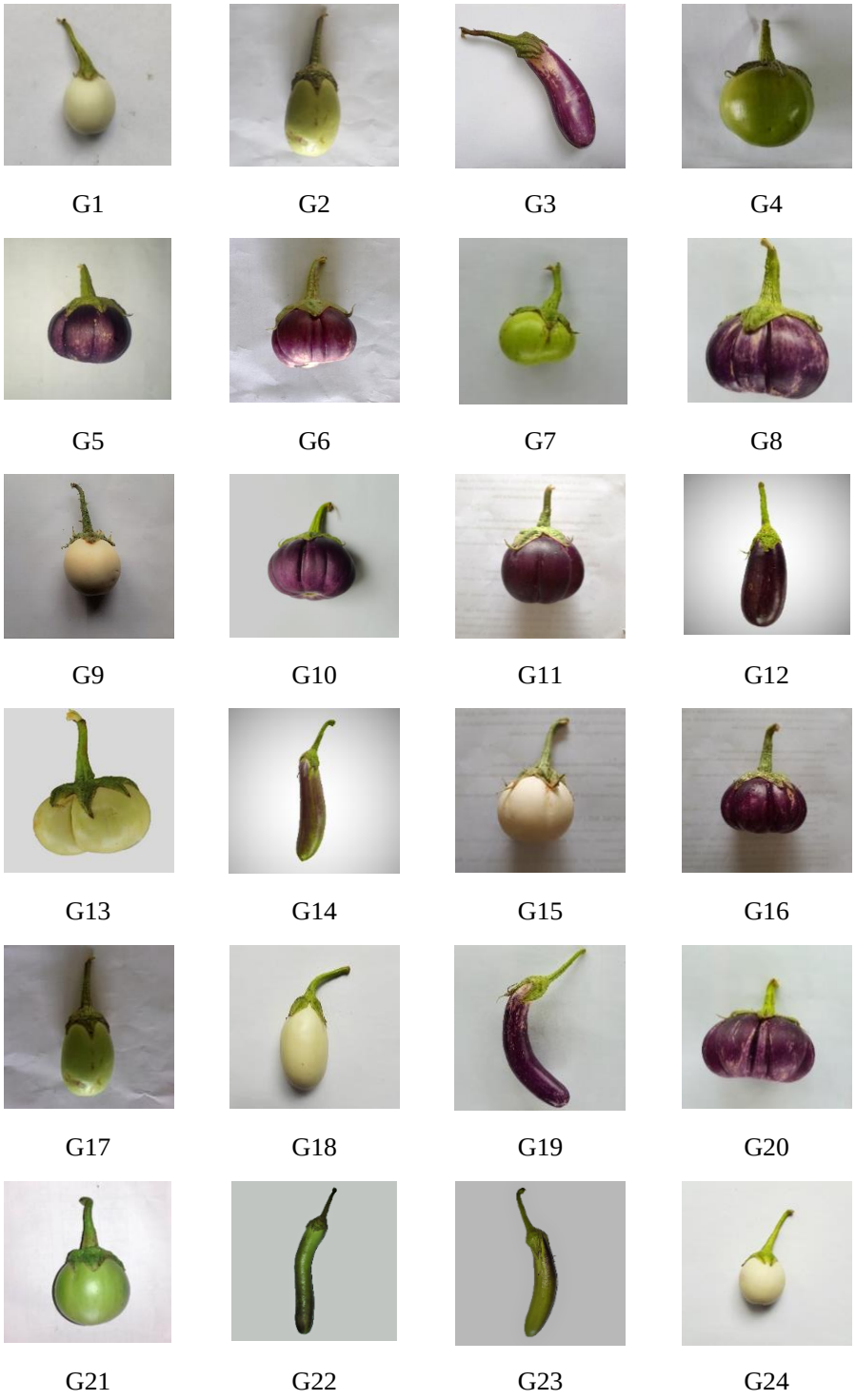

Figure 2. Variation in fruits among different brinjal lines/treatments.

(Source:Pranto,2022)

CHAPTER 4

CONCLUSION

Reviewing the findings of the seminar paper, the following conclusions could be drawn:

- The percent shoot infestation showed positive correlations with plant height and diameter of the top internode while the negative correlation with the number of primary branches per plant, number of leaves per plant, leaf trichome density, number of spines on the leaf. The percent fruit infestation showed a significant positive correlation with plant height, fruit diameter, fruit weight, days to first flowering, and days to first fruiting while a negative correlation with the number of primary branches per plant, number of fruits per plant, fruit length, number of leaves per plant, leaf trichome density.
- The Mid and late fruiting stage of the plant was mostly preferred by brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee). White color fruit had the lowest fruit damage and oval shape fruit had less infestation.
- In the context of resistant mechanisms against BSFB and morphological characters, G1, G3, G9, G14, G15, G18, G19, G23, G24, and G28 are the most appropriate brinjal lines/treatments. Further studies should be carried out to identify anatomical characters concerning resistance against BSFB to develop a superior brinjal variety resistant against brinjal shoot and fruit borer.

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