GROWTH AND YIELD PERFORMANCE OF EGGPLANT UNDER DROUGHT AND WATERLOGGING CONDITION

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CERTIFICATE

This is to certify that the thesis entitled **'GROWTH AND YIELD PERFORMANCE OF EGGPLANT UNDER DROUGHT AND WATERLOGGING CONDITION'** *submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***AGROFORESTRY AND ENVIRONMENTAL SCIENCE****, embodies the result of a piece of bona fide research work carried out by* ***FATEMA TUJ ZOHURA****, Registration number:* ***14-05970,*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated: JUNE, 2021

Dhaka, Bangladesh

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DEDICATION

I dedicated this thesis to my mother (Monowara Begum) and father (Md. Dudu Mia) for their extreme dedication to my whole life. I also devoted this thesis to my husband (Md. Al-Amin) for his inspiration and mental support.

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GROWTH AND YIELD PERFORMANCE OF EGGPLANT UNDER DROUGHT AND WATERLOGGING CONDITION

ABSTRACT

The production of eggplant is reduced due to climate change induced by major abiotic stresses like drought and waterlogging. So, the objective of this study is to explore the influences of drought and waterlogging conditions on morphological, physiological and yield attributes of the eggplant. The experiment was laid out by two factors Randomized Complete Block Design (RCBD) with three replications and comprised of three eggplant varieties with three treatment combinations Control (T_1), Drought (T_2) and Waterlogging (T_3). From the results it was found that both drought and waterlogging have affected significantly and reduced the morphological, physiological and yield of eggplant. BARI Begun-5 has been affected more with the treatments, whereas the Purple King showed the reverse trend. It was found that purple king revealed higher plant height (36.52 cm at 65 DAT), leaf number (35), SPAD value (57.4 SPAD value at 67 DAT) and fruit yield (1.48 Kg per pot) under control condition than in drought and waterlogging condition. Therefore, Purple King variety performed best both in drought and waterlogging condition.

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LIST OF ABBREVIATIONS

%	: Percentage
AEZ	: Agro Ecological Zone
ANOVA	: Analysis of Variance
BARI	: Bangladesh Agricultural Research Institute
BDRC	: Bangladesh development research center
CC	: Chlorophyll Content
cm	: Centimeter
CV	: Coefficient of Variation
DAT	: Day after transplantation
DF	: Degree of Freedom
IPCC	: Intergovernmental Panel on Climate Change
Kg	: Kilogram
m	: Meter
MS	: Mean Squares
SPAD	: Soil Plant Analysis Development
SS	: Sum of Squared
T	: Treatment
UNDP	: United Nation Development Program
V	: Variety

CHAPTER 1

INTRODUCTION

Eggplant (*Solanum melongena L.*) is a hot-weather vegetable that is commonly grown in tropical and subtropical regions all over the world. It is one of the popular vegetables and highly cultivated and consumed in Asia countries specially Bangladesh. This plant is indigenous to India and is found throughout Asia, with China serving as a secondary source of origin. Furthermore, in terms of acreage and production, eggplant is the second most important vegetable crop after potato, and the most important traditional vegetable in Bangladesh (Saifullah *et al*., 2012; Sabina *et al*., 2021). According to the Bangladesh Bureau of Statistics (BBS), it is cultivated by roughly 150,000 poor farmers on 50,955 hectares, with a total yield of 507,000 metric tons in 2018. In term of nutrition value of the eggplant, nutrients, minerals, antioxidants, vitamins, dietary fiber, and body-building components and proteins are abundant in it. Hence, Brinjal has a high nutritional content that is comparable to tomato (Choudhary, 1976). China, India, Egypt, Turkey, and Iran are the top five eggplant producers, with production of 28.4, 13.4, 1.2, 0.82, and 0.75 million tons, respectively (Taher *et al.*, 2017). Moreover, after potato, tomato, pepper, and tobacco, eggplant is the fifth most economically important solanaceous crop, with yearly production of roughly 50 million tons and a net worth of more than US$10 billion (Frary *et al*., 2007). In Bangladesh, an average yield of 10.00 tons per hectare has been recorded which is comparatively lower than that produced by the other countries (Anon, 2017).

In Bangladesh, eggplant plays an important role in both summer and winter, meeting market demand for vegetables and serving as a common cooking vegetable. It can be grown all year in Bangladesh, but it is most productive during the winter months. It should be grown in well-fertilized soil with plenty of compost for maximum yields (Hossain *et al*., 2013). Although several types of varieties of the eggplant are cultivating in numerous zones of Bangladesh, they have varying yield potentials, and their yield appears to be impacted greatly by several biotic and abiotic stresses (Sabina *et al*., 2021). Infestation of diseases and pests are examples of biotic factors, while drought, waterlogging, salinity, cold and heat stress are examples of abiotic stresses that reduce productivity (Prabhavathi and Rajan, 2007). These are the key factors which influence the yielding of eggplant because the crop especially eggplant which shows a moderate sensitivity on both drought and waterlogging conditions. The hybridization approaches are limited to achieve the desired stress tolerance in the hybrid eggplant due to sexual incompatibility, the predominance of sterility in the progeny, and the lack of natural sources of resistance (Sabina *et al*., 2021; Mogioli and Mansur, 2005), whereas the genetic engineering method enables to transfer the desired tolerance characteristics in the eggplant (Sabina *et al*., 2021).

As a result of climate change, irregular climate conditions represent a significant threat to humanity, resulting in droughts and waterlogging. Drought in agriculture refers to a lack of sufficient moisture for regular growth and development of plants to complete the life cycle (Manivannan *et al*., 2008). Drought has a significant impact on plant growth and development, resulting in lower crop growth rates and biomass accumulation. Brinjal is regarded to be moderately drought tolerant (Bsoul *et al*., 2016). The most drought-affected area in Bangladesh is in northwestern Bangladesh, which has higher rainfall variability and a drier environment. Water stress has a direct impact on plants by reducing nutrient and water intake, as well as an indirect effect on physiological processes such as photosynthesis, respiration, glucose metabolism, and translocation, as well as a reduction in the production of various plant growth hormones (Farooq *et al.*, 2008). Main cause of crop losses in worldwide is the environmental stress, reported average yield reduction of major crops by more than 50% (Bray *et al*., 2000). Waterlogging is an abiotic stress severely affects crop growth and yield characteristics (Linkemer *et al*., 1998; Setter and Waters, 2003; Lone *et al*., 2018). Flooding, overflow of sea water, excess rainfall, insufficient drainage systems and other factors are owing to waterlogging (Lone *et al*., 2018). Floods are an annual occurrence in Bangladesh, with the worst flooding happening in July and August. River floods inundate roughly 20% of the country on a regular basis, with extreme years inundating up to 68 percent. Global climate change makes the waterlogging more drastic, frequent and unpredictable (Jackson and colmer, 2005). Increased internal ethylene concentration, low stomatal conductance, decreased leaf, root, and shoot development, alterations in osmotic potential and nutrient uptake, and reduced chlorophyll content and photosynthesis are all responses of the plants to waterlogging (Ashraf *et al*., 2011 and Malik *et al.*, 2001). Oxygen deficiency is the key result of waterlogging induces the sensitivity of crops like tomato, eggplant, annona species growth and yield (Walter, 2004 and Ezin *et al*., 2010). Moreover 10% agricultural land of Russia, 16% of soil and irrigated crop production areas of Bangladesh, Pakistan, India & China are affected by waterlogging ((Yaduvanshi *et al*., 2014; FAO, 2015). Geographical position of Bangladesh leads to accept waterlogging and drought as a pressing concern. However adequate adoption of prevention and mitigation measures is now a time demanding step to ensure agricultural production and food security.

Although the eggplant has a great importance on the economy and nutrition, the yield of it significantly depends on the climatic conditions, varieties and soil conditions. There is still a lack of information regarding the impacts of both yield and growth responses of eggplant with different abiotic stresses. There are a few research activities, which worked on the influence of both drought and waterlogging conditions on yield and growth characteristics of eggplant leading to a need for the research.

Therefore, considering the mentioned facts the present study was carried out to fulfill the following objectives:

1) To evaluate the influences of both drought and waterlogging conditions on the vegetative growth of eggplant and physiological responses and
2) To assess the variations of eggplant's yield under the different drought and waterlogging conditions

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

This chapter discusses an overview of the eggplant and its socio-economic importance as well as varieties available in Bangladesh. This chapter also includes the climate changes induced drought and waterlogging and their effects on the growth and yield responses of eggplant and other vegetables. A comprehensive review on the previous studies has been presented.

2.2 Overview of eggplant

Eggplant (*Solanum melongena L*.) is a Solanaceae plant that is widely produced as a vegetable crop in many parts of the world, including tropical areas such as Bangladesh, India, China, and the Middle East (Sarhan *et al.*, 2011). In Bangladesh, eggplant crops can be grown all year, but are most fruitful during the winter (rabi) and summer (kharif) seasons. This plant is native to India and can be found all across Asia, with China as a secondary source of origin. In addition, eggplant is Bangladesh's second most important vegetable crop behind potatoes in terms of acreage and production, as well as the most important traditional vegetable (Saifullah *et al*., 2012; Sabina *et al*., 2021). Nutrients, minerals, antioxidants, vitamins, dietary fiber, and body-building components and proteins abound in eggplant, giving it a high nutritional value. It also contains 0.7 milligrams of iron, 13.0 milligrams of sodium, 213.0 milligrams of potassium, 12.0 milligrams of calcium, 26.0 milligrams of phosphorus, 5.0 milligrams of ascorbic acid, and 0.5 milligrams of vitamin A per 100 gram serving, and offers 25.0 calories (Saeedifar *et al*., 2014). Figure 1 depicts an overview of nutrition values of the eggplant.

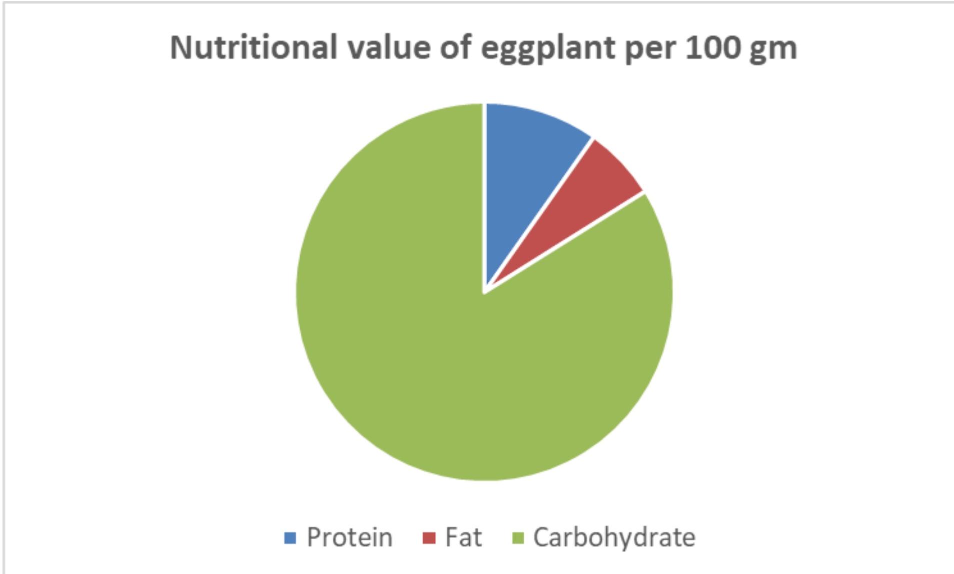

Figure 1. Nutrition value of eggplant (*Saeedifar et al.*, 2014)

2.3 Socio economic importance and present status of eggplant

Eggplant is a well-known vegetable crop due to its ease of preparation, superior flavor, and reduced market price. It is widely grown in almost all of Bangladesh's districts. Because of its popularity, especially among urban residents, it can be grown in the homestead and kitchen garden. The cultivation of eggplant is carried out by around 8 million agricultural families (Islam, 2005). It provides a steady source of income for small, marginal, and landless farmers, as well as employment opportunities for the rural residents. Moreover, it is a key part of crop agriculture in Bangladesh, contributing $718 million (3.2 percent) to the country's agricultural GDP in 2010 (BBS, 2012). The vegetable production has been increased in the recent years. In 2008-2009, there were 356.6 thousand hectares under vegetable cultivation with an average yield of 1.3 ton/hectare, but in 2010-2011, there were 367.6 thousand hectares under vegetable production with an average yield of 1.3 ton/hectare (Yearbook of Agricultural Statistics of Bangladesh, 2011). In terms of their producing period, eggplant is divided into two types. These are Rabi eggplant and Kharif eggplant. Though it is available throughout the year, the months of December to April are when it is most plentiful. According to the Bangladesh Bureau of Statistics (BBS), it is grown on 50,955 hectares by 150,000 impoverished farmers, yielding 507,000 metric tons in 2018. Figure 2 provides information on the GDP shared by eggplant and other crops in Bangladesh. With annual production of almost 50 million tons and a net worth of more than US$10 billion, eggplant is the fifth most economically important solanaceous crop after potato, tomato, pepper, and tobacco (Frary *et al*., 2007).

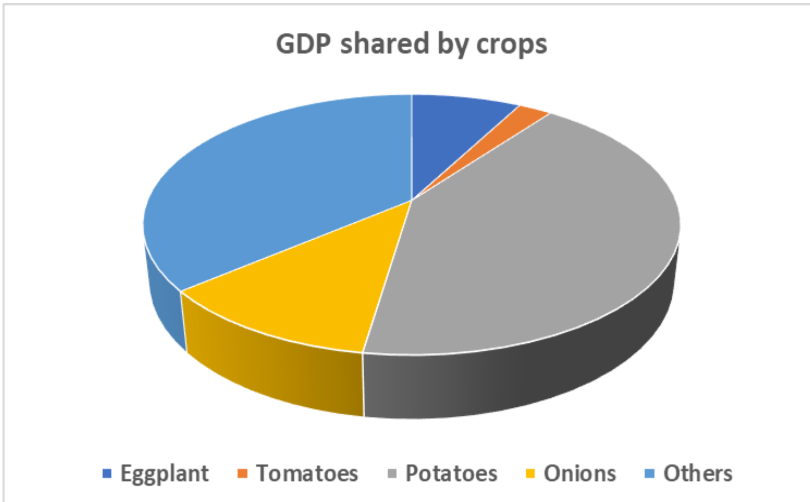

Figure 2. GDP shared by eggplant and other crops (Source, BDRC)

2.4 Available eggplant varieties in Bangladesh

There are some eggplant varieties, which are available in Bangladesh for cultivation. These have different color, shape, yield per hectare, life duration, fruit number per plant, and fruit weight. According to krishi projukti hatboi, available eggplant varieties in Bangladesh and their characteristics are discussed below.

2.4.1 BARI Begun-1 (Uttara)

Life span:160-170 days, Fruit/plant: 50-55, Yield/ha: 50-55ton, Fruit color: violet.

2.4.2 BARI Hybrid Begun-2 (Tarapuri)

Life span: 180-190 days, Fruit/plant: 40-45, Yield/ha: 55-60 tons, Fruit color: Blackish violet.

2.4.3 BARI Begun-4 (Kajla)

Life span: 180-190 days, Fruit/plant: 50-55, Fruit wt: 90-100gm, Yield/ha: 50-55 tons, Fruit color and shape: Blackish violet and longer.

2.4.4 BARI Begun-5 (Nayantara)

Life span: 160-180 days, Fruit/plant: 30-32, Fruit wt: 150-160 gm, Yield/ha: 45-50 tons, Fruit color and shape: Bright blackish violet and round.

2.4.5 BARI Begun-6

Life span: 170-190 days, Fruit/plant: 20-22, Fruit wt: 200-225 gm, Yield/ha: 45-50 tons, Fruit color and shape: Greenish and oval.

2.4.6 BARI Begun-7 (Singnath)

Life span:160-180 days, Fruit/plant: 30-35, Fruit wt: 110-120 gm, Yield/ha: 40- 45 tons, Fruit color and shape: Bright deep violet and long, slender.

2.4.7 BARI Begun-8

Duration: Year-round, Fruit/plant: 30-35, Fruit wt: 115-120 gm, Yield/ha: 45-50 ton(winter), Fruit color and shape: Bright blackish violet and long slender.

2.4.8 BARI Begun-9

Fruit/plant: 30-35, Fruit wt: 130-140 gm, Yield/ha: 42- 45 tons, Fruit color and shape: Greenish and oval.

2.4.9 BARI Begun-10

Duration: Year-round, Fruit/plant: 25-30, Fruit wt:120-130 gm, Yield/ha:45-50 tons, Fruit color and shape: Bright deep violet and long, slender.

2.4.10 BARI Hybrid Begun-3

Life span:170-180 days, Fruit/plant: 50-55, Fruit wt: 100-110 gm, Yield/ha: 55-60 tons, Fruit color and shape: Deep violet and cylinder.

2.4.11 BARI Hybrid Begun-4

Life span:140-150 days, Fruit/plant: 45-50, Fruit wt: 110-120 gm, Yield/ha: 40- 45 tons, Fruit color and shape: Greenish and oval.

2.4.12 Purple king (A local variety)

Duration: Year-round, Fruit/plant: 40-45, Fruit wt:110-130gm, Yield/ha: 50-55 tons, Fruit color and shape: Deep purple and oval.

2.5 Climate changes

Water and agriculture are projected to be the most vulnerable sectors to climate change-related consequences, which would have a detrimental influence on food production and thus raise food costs. With limited land and water supplies, a big population, and constraints imposed by topography, soil conditions, aridity, and a large number of disaster-prone locations, the south Asian region, including Bangladesh, has become one of the world's most vulnerable climate change regions (GWP SAS, 2012). Climate influences plant growth by impeding, encouraging, and modifying crop performance, which has a significant impact on agricultural productivity. Bangladesh, according to the IPCC, will be one of the most affected by climate change. Apart from that, the majority of climate change's negative effects will manifest themselves in extreme weather events, while water-related hazards such as flood, drought, salinity ingress, bank erosion, and tidal bore are likely to worsen, resulting in large-scale crop, employment, livelihood, and national economy losses (Shaw *et al*., 2013). By 2030, an extra 14% of the country is expected to be severely vulnerable to the flooding. At the same time, during the dry season, some parts of the country may be more vulnerable to the drought and food poverty, while agricultural production in coastal areas may be affected by rising the salinity (Hussain, 2011). Climate change has resulted in lower precipitation during the dry season and increased precipitation during the monsoon season in south Asia as a result of global warming (Christensen *et al*., 2007). According to the IPCC (2007), due to ice melting and more stronger monsoons, Bangladesh would experience more droughts outside of the monsoon season, as well as severe floods.

2.5.1 Drought stress

Drought in agriculture refers to a lack of sufficient moisture for regular plant growth and development to complete the life cycle (Manivannan *et al*., 2008). Agricultural drought is caused by a prolonged lack of precipitation (meteorological drought) combined with a higher evapotranspiration demand (Mishra and Cherkauer, 2010). Drought has a significant impact on plant growth and development, resulting in a lower crop growth rates and biomass accumulation. Drought reduces the rate of cell division and expansion, leaf size, stem elongation, and root proliferation in crop plants, as well as disrupting stomatal oscillations, plant water and nutrient interactions, crop yield, and water usage efficiency (Li *et al*., 2009; Farooq *et al*., 2009a). Figure 3 demonstrates the drought stress and its effect on plant.

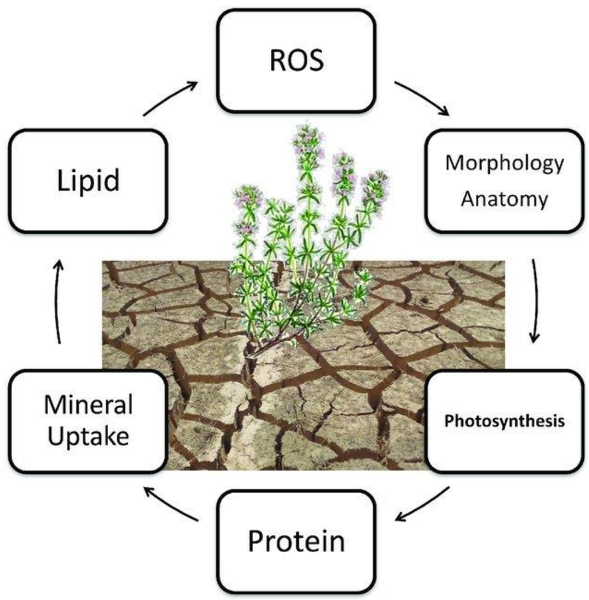

Figure 3. Drought stress and its impact on plant (Parviz Moradi, 2016)

From Figure 3, drought stress alters the reactive oxygen species (ROS) of plant resulting in a change in morphological anatomy caused by reduction of mineral uptake and production of protein and lipid. Moreover, photosynthesis process is hampered. Drought intensity and frequency are expected to grow under current global climate change scenarios, according to climate models (IPCC 2007; Walter *et al*., 2011). Drought is a complicated environmental calamity with devastating consequences for wildlife, agriculture, and the economy. Drought affects more people than any other category of natural disaster (Barlow *et al*., 2006). It has become more common and severe in recent years as a result of a number of variables, including climate change. Droughts have affected extensive parts of Europe, Africa, Asia, Australia, South America, Central America, and North America, resulting in substantial economic losses, food shortages, and, in some cases, hunger for millions of people (Kogan *et al*., 2013). When drought strikes, agriculture is always the first to be impacted (Mazid *et al*., 2005). Drought's negative consequences are usually amplified if it happens in an agrarian and heavily populated region, such as South Asia, where millions of people rely on various agricultural activities directly or indirectly However, in some places of South Asia, such as Bangladesh, the severity of drought has been greatly decreased by intensive irrigation, which uses readily available but rapidly dwindling underground water for the growth of high yield variety (HYV) Boro rice (Dey *et al*., 2013). Bangladesh is one of the world's most drought-prone countries, despite the fact that widespread irrigation has lessened the severity of pre-monsoon dryness in many parts (Brammar, 1987). The most drought-affected area in Bangladesh is in northwestern Bangladesh, which has higher rainfall variability and a drier environment (Shahid and Behrawan, 2008). The 2006 data indicated that drought caused 25 –30% crop reduction in the northwestern part of Bangladesh (Rahman *et al*., 2008). Drought not only has caused loss of crop production but also has social and environmental impacts.

Drought is defined in Bangladesh as a period during which the moisture content of the soil is less than what is required for satisfactory crop growth during the typical crop-growing season (Banglapedia, 2006). Bangladesh has experienced an increase in drought frequency in recent years, according to the National Drought Mitigation Center (2006). Bangladesh has a 7-month dry season every year, from November to May, when rainfall is typically low. Bangladesh has had severe droughts in the years 1973, 1978, 1979, 1981, 1982, 1992, 1994, 1995, 2000, and 2006 (Shahid and Behrawan, 2008). Droughts have a negative impact on Bangladesh's crop production. Drought destroys 2.32 million hectares of cultivable T-aman (rice variety) in the kharif season and 2.2 million hectares of rabi crops in the rabi season, depending on the severity of the drought. Drought-related yield decreases in T-aman crops range from 45 to 60%, whereas rabi crop yield reductions range from 50 to 70% (Climate Change Cell of Bangladesh, 2009).

2.5.2 Waterlogging stress

Waterlogging is a worldwide occurrence and a specific abiotic stress that has an impact on crop growth and output. Waterlogging events are becoming increasingly common, severe, and unexpected as a result of global climate change. Heavy rainfall, insufficient drainage systems, natural flooding, and other factors can create waterlogging (Linkemer *et al*., 1998; Setter and Waters, 2003; Lone *et al*., 2018; Jackson and Colmer, 2005). About 10% of the global land area is affected by flooding (Setter and Waters, 2003). Moreover 16% of soils are affected by waterlogging in USA alone and the economic losses due to crop production are estimated to be the second largest after drought (Zhou, 2010). In a waterlogged root environment, oxygen levels quickly deplete. Flooding is a natural disaster that significantly restricts crop growth and yield. In rain-fed environments, waterlogging and flooding are prevalent, especially in soils with inadequate drainage. Flooding and waterlogging are two stresses that the Food and Agriculture Organization (FAO) and the International Institute for Applied Statistical Research considered in their estimations of world arable land area and global production (Dennis *et al*., 2000; Fischer *et al*., 2001). Flooding can result in yield reduction ranged from 10% to 40% (Bange *et al*., 2004; Hodgson and Chan, 1982). Waterlogging is the consequence of flooding, intensive and large-scale irrigation scheme and inadequate drainage. Figure 4 shows a comparison between waterlogging and flooding conditions.

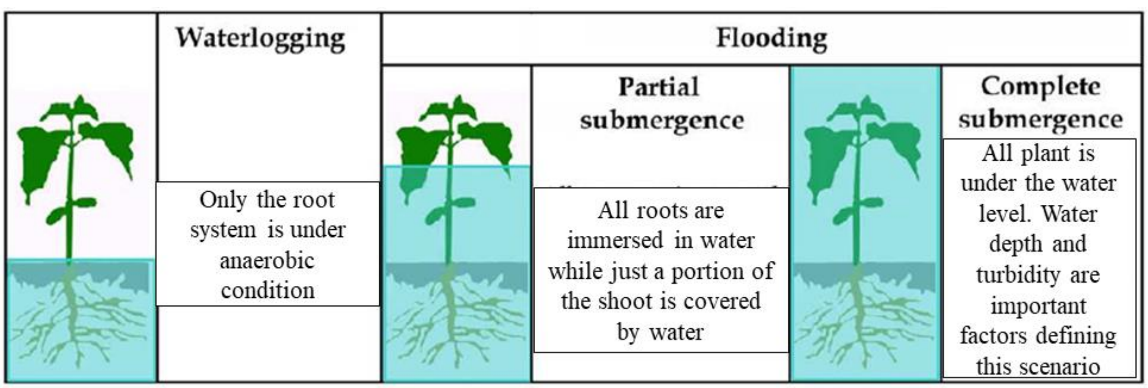

Figure 4. Comparison between waterlogging and flooding conditions (Striker, 2012)

Waterlogging is also known to have negative impacts on plant physiological and biochemical processes by causing nutritional deficiencies such as nitrogen, magnesium, potassium, and calcium. Species with naturally surface-inhabiting root systems are particularly resistant to waterlogging. Breeding waterlogging tolerant cultivars, improving drainage systems, and modifying crop husbandry are all approaches for mitigating submergence and waterlogging problems. However, waterlogging concerns can be alleviated by providing enough drainage and foliar fertilizer and hormone sprays. For high-value crops, bed planting in waterlogged areas and floating beds in flooded areas are viable solutions (Ashraf *et al*., 2005).

2.6 Effects of drought and waterlogging on plant

2.6.1 Impacts of drought on plant responses

More than any other environmental component, drought, as the most critical environmental stress, severely inhibits plant growth and development, reduces plant yield, and negatively impacts agricultural plant performance (Shao *et al*., 2009). Adaptive alterations in plant development and physio-biochemical processes, such as changes in plant structure, growth rate, tissue osmotic potential, and antioxidant defenses, occur when plants become acclimated to water deficits (*Duan et al*., 2007). Drought stress causes plants to undergo a variety of morphological, physiological, and biochemical changes. Figure 5 illustrates the mechanism of drought reactions in plant.

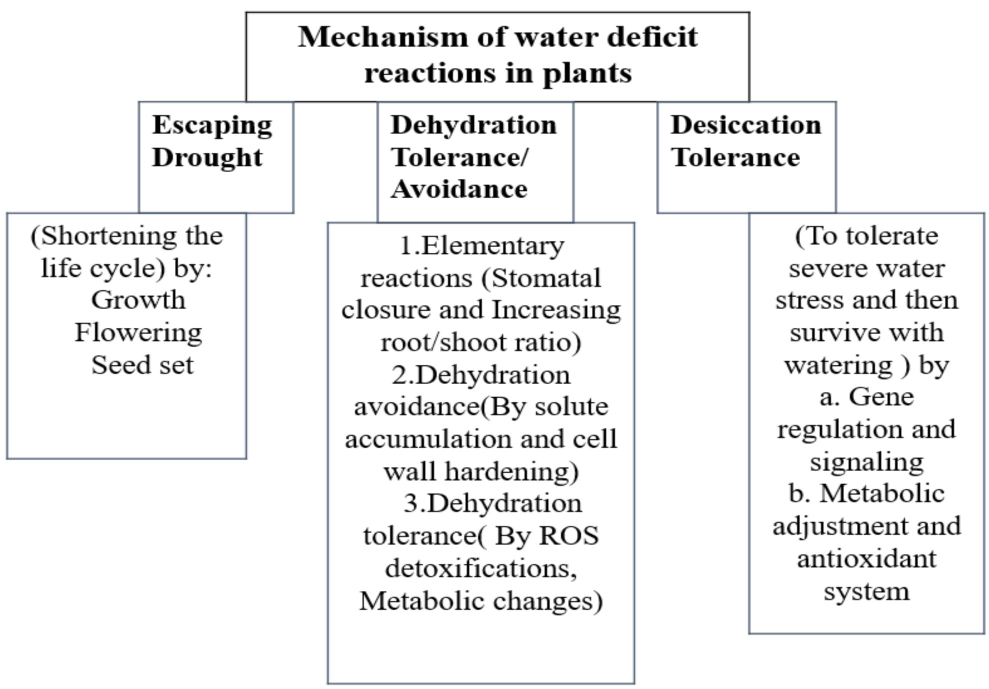

Figure 5. Mechanism of drought reactions in plant (Parviz Moradi, 2016)

2.6.1.1 Morphological and yield contributing responses

More than any other environmental condition, a permanent or temporary water shortage severely impedes plant growth and development. Drought has several effects, the first of which is reduced germination and stand establishment (Harris *et al*., 2002). Drought hampered mitosis, resulting in lower growth and yield attributes due to cell elongation and expansion (Hussain *et al*., 2008). Higher plant cell elongation can be stopped by interrupting water flow from the xylem to the surrounding elongating cells when there is a severe water shortage (Nonami, 1998). By reducing the soil's water potential, water deficiencies lower the number of leaves per plant and individual leaf size, as well as leaf longevity. The suppression of leaf expansion due to reduced photosynthesis is thought to be the cause of drought-induced reduction in leaf area (Rucker *et al*., 1995). The decline in fresh and dry biomass output is a common side effect of water stress on crop plants (Zhao *et al*., 2006). Under water stress, the plant's height may be reduced due to a decrease in cell expansion and increased leaf senescence (Manivannan *et al*., 2007a). Shahbaz *et al*., (2015) found that bitter gourd plants exposed to various levels of water stress had stunted root growth.

Drought stress has a significant impact on plant yield contributing variables. Drought during flowering often leads to barrenness. Drought stress caused a significant loss in yield and yield components such as kernel rows/cob, kernel number/row, 100 kernels weight, kernels/cob, grain yield/plant, biological yield/plant, and harvest index when maize plants were exposed to drought stress at the tasseling stage (Anjum *et al*., 2011a). Drought-stressed soybean plants produced fewer pods, fewer seeds per pod, and a smaller seed mass than plants that were properly irrigated (Dornbos *et al*., 1989). According to Kamara *et al*., (2003), a water deficit induced at various developmental stages of maize reduced total biomass accumulation by 37% during silking, 34% at grain filling, and 21% at maturity.

2.6.1.2 Physiological and biochemical responses

Climate change has exacerbated water stress, which has a direct impact on plant growth by reducing nutrient and water uptake, as well as an indirect impact on physiological processes such as photosynthesis, respiration, carbohydrate metabolism, and translocation, as well as a reduction in the production of various plant growth hormones (Farooq *et al*., 2008). Photosynthesis and chlorophyll measurements can be utilized as a significant predictor of water stress in eggplant, according to Inalpulat *et al.*, 2014. A prolonged and severe water stress stunted growth by lowering photosynthetic rate through stomata closure and metabolic impacts on photosynthesis (Hsiao *et al*., 1985). Many studies have revealed that drought stress reduces photosynthetic activity through stomatal or non-stomatal processes (Ahmadi, 1998; Del Blanco *et al*., 2000; Samarah *et al*., 2009). Stomata are the points of entry for water loss and CO2 absorption, and stomatal closure is one of the earliest responses to drought stress, resulting in a reduction in photosynthetic rate. Crop plants' ability to acclimatize to varied environments is directly or indirectly linked to their ability to acclimate at the level of photosynthesis, which impacts biochemical and physiological processes and, as a result, the whole plant's development and yield (Chandra, 2003). Drought stress in maize, according to Anjum *et al.* (2011a), resulted in a significant decrease in net photosynthesis (33.22%).

Many species have reported decreased or unchanged chlorophyll levels during drought stress, depending on the duration and severity of the drought (Kpyarissis *et al*., 1995; Zhang and Kirkham, 1996). The decrease in chlorophyll content under drought stress has been considered a typical symptom of oxidative stress. Both the chlorophyll a and b are prone to soil dehydration (Farooq *et al*., 2009). Drought stress reduced the amount of chlorophyll a, chlorophyll b, and total chlorophyll in many sunflower cultivars (Manivannan *et al*., 2007b).

According to Nayyar and Gupta (2006), drought stress causes a drop in relative water content (RWC) in a wide variety of plants. The interplay of drought intensity, duration, and species had an impact on RWC (Yang and Miao, 2010). Drought stress caused a significant drop in leaf water potential, relative water content, and transpiration rate, as well as an increase in leaf temperature (Siddique *et al*., 2001).

Reactive oxygen species (ROS) are the major biochemical responses of eukaryotic cells to biotic and abiotic stresses including drought and waterlogging. During drought, reactive oxygen species (ROS) levels has increased. It causes oxidative damage of proteins, DNA, and lipids (Apel and Hirt, 2004).

Drought stress tolerance plants is regulated by ABA. The ABA and drought stresses exerted the strongest effects on all hormones. Drought conditions dramatically increase the ABA level, which induce the expression of many stress-related genes and activate signal transduction pathways that leads stomatal movement.

2.6.2 Impacts of waterlogging on plant responses

2.6.2.1 Morphological and yield contributing responses

Plants experience morphological, physiological, and biochemical alterations as a result of waterlogging. Although water is chemically harmless, some physical features interfere with free gas exchange, causing plants to be injured or killed when completely submerged (Jackson *et al*., 2003) or even when only the soil is waterlogged (Vartapetian *et al*., 1997). In terms of yield, vegetable crops are more susceptible to waterlogging than field crops. Waterlogging affects about 10-15 million hectares of wheat worldwide, resulting in output losses of 20 to 50 percent per year (Hossain and Uddin, 2011).

Table 1. Growth response of the crops under waterlogged condition

Crop	Duration	Growth stage	Response	Reference
Tomato	3 days	One month	Reduced stem growth	Kuo and Chen (1980)
Soybean	7 days	15 DAS and 30 DAS	Stunted plants, reduced plant stand, delayed maturity and Seed weight reduction	Herrera and Zandstra (1979)
Pea	3 days	Flowering stage	Increased foliar hydration, 10-fold increase in endogenous ABA concentration	Jackson and Hall(1987)

Table 1 provides information on the growth response of a few crops under waterlogged condition. Other grain crops, such as barley, canola, lupins, field peas (Bakker *et al*., 2007; Romina *et al*., 2018), lentils, and chickpeas, are also affected by waterlogging (Solaiman *et al*., 2007).

Because of altered physiological processes, the consequences of waterlogging on winter crops are mainly seen as lower growth and chlorosis of older leaves (Ellington, 1986). Inhibiting gas exchange within the root zone has the potential to harm roots, limiting the plant's ability to absorb water and nutrients. Poor root development and delayed nitrogen uptake from the anaerobic soil cause chlorosis in older leaves (Belford *et al*., 1992). Perez reported that in tomato plant 3 days waterlogging at flowering stage resulted an increase in adventitious root. Annona species (Nunez-Elisea, 1999), *Panicum antidotale* (Ashraf, 2003), *Paspalum dilatatum* (Vasellati, 2001), and tomato all showed a reduction in plant growth owing to floods (Walter, 2004; Ezin *et al*., 2010).

Table 2. Symptoms of waterlogged solanaceous crops

Crops	Symptoms	Reference
Eggplant	Yellowing of the bottom leaves and a brown discoloration in the stem interior. Prolonged periods of very wet conditions may also promote rapid growth of rot pathogens	www.rma.usda.gov/pilots/feasible/pdf/eggpl ant.pdf
Tomato	Rapid development of downward growth of leaf petioles	Jackson and Cambell, 1976
Potato	The potato plant is sensitive to even short periods of moderate water stress. Water stress is usually reflected in slower growth, a smaller leaf canopy, early senescence and eventually in lower yields.	http://nbsystems.co.za/potato/index_27.htm
Okra	Decrease in photosynthetic rate, water use efficiency and intrinsic water use efficiency	Ashraf and Arfan, 2005
Chili	Leaf yellowing or fall off. Wilting can also be sign of poor drainage.	http://www.ehow.com/info_8279955_drainage-dying-chilli-plants.html

Table 2 presents data on the symptoms of waterlogged solanaceous crops. According to Ezin *et al*. (2010), the magnitude of the change in reproductive growth varies depending on the plant species and genotype, as well as the time and duration of flooding. Waterlogging of soil often stops floral bud initiation, anthesis, fruit set, and fruit enlargement in flood-intolerant species, according to Ezin *et al*., 2010 and Kozlowski, 1997. Fruit set was reduced by 45 percent in flooded *V. corymbosum*, according to Abbott and Gough, 1987.

2.6.2.2 Physiological and biochemical responses

Flood-stressed plants have increased stomata resistance and restricted water intake, resulting in an internal water deficit (Folzer *et al*., 2006) and oxygen deficiency. Oxygen shortage causes a significant decrease in net photosynthetic rate (Yordanova *et al*., 2004). Stomata closure is responsible for the decrease in transpiration and photosynthesis (Liao and Lin, 1994). Other factors, including as reduced chlorophyll concentration, leaf senescence, and reduced leaf area, have also been blamed for lower photosynthetic rates (Li *et al*., 2010). The concentration of ROS in waterlogged plants is higher than in normal plants. Proteins, lipids, pigments, photosynthesis, PS II efficiency, DNA, and other cellular components, metabolic events, and metabolites are all damaged by ROS (Xu *et al*., 2014 and Zhang *et al*., 2017). Plants exposed to flooding for an extended period of time may suffer root injuries, which can reduce photosynthetic capacity by causing biochemical changes in photosynthesis. Loreti *et al*., 2016 reported that a variety of plants, such as *Lycopersicon esculentum*, *Pisum sativum* and *Triticum aestivum*, suffer a significant loss in photosynthetic capability as a result of waterlogging. Under soggy/waterlogged conditions, decrease in chlorophyll has a direct or indirect effect on plant photosynthetic capacity (Loreti *et al*., 2016). Diffusion of gases through soil pores is significantly impeded by water in waterlogged soil, and so fails to meet the needs of growing roots. The main cause of harm to roots and the shoots they support is a decreasing oxygen influx (Luan *et al*., 2018).

2.7 Effect of Drought and Waterlogging on Eggplant

2.7.1 Impact of Drought on Eggplant

Drought or moisture stress has become a major output limiting factor in Bangladesh as a consequence of climate change. Some research has been done on eggplant productivity, morphological, and physiological responses when water is scarce. Where fruit output, quality, plant vegetative development, and photosynthetic activity were all reduced, whereas stomatal resistance was increased in the majority of cases (Lovelli *et al*., 2007). In reaction to water stress, eggplant cultivars' growth and yield characteristics differed significantly. Drought stress affects eggplant in a modest way (Bsoul *et al*., 2016). Given the growing water scarcity in the agricultural sector, it's critical to understand how different eggplant cultivars respond to moisture stress (Akinci *et al*., 2004). Some eggplant varieties are affected by water stress and grow shorter (Hussein *et al*., 2007; Ilahi *et al*., 2018). According to Bafeel and Moftah, 2008, the negative impact of drought stress on eggplant yield and components may be due to a reduction in vegetative growth. Abd El-Al *et al*., 2008 found that irrigating eggplant at 10-day intervals resulted in greater plant growth and a heavier total yield. As water stress intensified, the number of branches and leaves per plant reduced in eggplant (Ilahi *et al*., 2018). Drought stress induced similar findings have also been reported in tomato (Pervez *et al*., 2009), Okra (Kusvuran, 2012) and bottle gourd (Sithole and Modi, 2015) cultivars. Under water-stressed conditions, root length may be reduced due to slowed cell development and division. Zayova *et al*., 2017 found a similar finding for root length of in vitro grown eggplant, where water stress reduced root length considerably when compared to control. The reduction in root length of eggplant and okra under drought stress was confirmed by Altaf *et al*., 2015.

Drought stress influenced photosynthetic responses, fruit soluble solid content, and eggplant yield, according to Inalpulat *et al*., 2014. In greenhouse-grown eggplant, a lack of water in the soil reduced the number of fruits but not their size (Chartzoulakis and Drosos, 1995). When compared to plants that got regular irrigation during their growth and development, eggplants that were subjected to drought stress produced fewer blooms and had poorer fruit set (Aujla *et al*., 2007; Sithole and Modi, 2015). Water stress reduced the leaf area of eggplants and harmed hormonal balance, plant development, and assimilate translocation, according to Madramootoo and Rigby, 1991, Salisbury and Ross, 1992 and Kirnak *et al*., 2001. Drought stress also resulted in a significant reduction in chlorophyll content and plant height of eggplants compared to control, according to Madramootoo and Rigby, 1991, Salisbury and Ross, 1992. Flowering and fruit development are critical stages for eggplants in terms of water requirements. Reduced yield and poor color development in the fruit are the effects of a lack of water on eggplant (Kemble and Sanders, 2000).

2.7.2 Impact of waterlogging on Eggplant

Because of altered physiological processes, the impacts of waterlogging on winter crops, including eggplant, are frequently seen as lower growth and chlorosis of older leaves (Ellington,1986). The morphology of eggplants is affected by waterlogging, with yellowing of the bottom leaves and a brown discoloration in the stem core. Accordingly prolonged periods of very wet conditions may also promote rapid growth of rot pathogens in eggplant. Waterlogging did not result in a substantial increase in eggplant yield but did result in a drop in yield (Senyigit *et al*., 2011). The impact of waterlogging on eggplants output is determined by the frequency and duration of the waterlogging event(s), as well as the timing of the event(s) in relation to the crop's growth stage (Johnston, 1999). When waterlogging occurs during germination or the early vegetative phases, it has the biggest negative impact on crop production (Cannell *et al*., 1980). All of these studies suggest that eggplants respond to waterlogging stress in different ways.

CHAPTER 3

MATERIALS AND METHODS

This chapter goes into enough depth about the methods and materials used in this study to meet the set objectives. This chapter also includes the step-by-step experimental approaches such as experimental site, experimental materials, seedling preparation, experimental design, pot preparation, data collection procedure and data analysis. A detail of data collection procedure with the instruments involved has been presented so that anyone can repeat the methods for further use.

3.1 Experimental site

The experiments were carried out in the plastic pots at the experimental site of Agroforestry and Environmental Science field Lab located at Sher-e-Bangla Agricultural University, Bangladesh. The experiment was conducted in the Rabi season, which is ranged from October 2019 to March 2020. According to the Bangladesh Metrological Department, Agargaon, Dhaka-1207, the experimental site was located at 23^{o}75' N latitude and 90^{o}34' E longitudes, at a height of 8.45 meters above the sea level (Anon., 1989).

3.2 Materials

3.2.1 Soil and fertilizer

The experimental site is located in the Modhupur Tract (UNDP, 1988) under AEZ No. 28, and the adopted soil has a medium texture with appropriate irrigation facilities. The sandy loam soil utilized in the experimental pot was acquired from SAU Field. Average pH and temperature of the employed soil were 6.5 and about 29^{o}C. The fertilizer known as Urea, TSP (Triple super phosphate), MP (Muriate of potash) and cow dung was used in the experiments.

3.2.2 Climate

The experimental site is located in a subtropical climate zone with considerable rainfall from April to September (Kharif season) and little rainfall from October to March (Rabi season). During Rabi season, there is a plenty of sunshine and the temperature is partially cool.

3.2.3 Pot selection

In this study, 27 sets of the plastic pots have been adopted, which had a diameter of 30 cm and a height of 25 cm.

3.2.4 Eggplant variety

In this research, three types of eggplant variety including BARI Begun-5 (Nayantara), BARI Begun-7 (Singnath) and Purple King local have been selected.

3.3 Methods

3.3.1 Seedling preparation

The seeds of BARI Begun-5 (Nayantara), BARI Begun-7 (Singnath) and Purple King local have been brought from BARI, Joydebpur, Gazipur, which were sown in the different plastic pots on 13 November, 2019 for raising the seedlings. Figure 3.1 shows the raised seedlings in the plastic pot.

Plate 1. The seedlings in the plastic pots

3.3.2 Pot preparation

For a pot preparation, the sandy loam soil was used. The soil was absolutely free of weeds and stubbles. The soil was crushed extensively, dried in the sun, then thoroughly mixed with the decomposed cow dung (3:1), urea (350 gm), TSP (500 gm), and MP (250 gm). To keep the soil free of pathogens, it was treated with a small amount (25 gm) of sevin powder. Each pot contains about 7 kg of the ingredient mixture. The pots were filled up 15 days before transplanting.

3.3.3 Transplantation of seedlings

Transplanting of the seedlings was done on 25 December, 2019 at 4.30 pm. 30 days old seedlings of BARI Begun-5, BARI Begun-7 and Purple king local were grown in plastic pot at the experimental field of Sher-e-Bangla Agricultural University. Figure 3.2 depicts transplantation of the seedlings in the pots.

Plate 2. Transplantation of seedlings in the pots

3.3.4 Design and layout of experiments

Three eggplant cultivars were treated in a two-factor experimental design using a RCBD approach with three replications under control (T1), drought (T2), and waterlogging (T3) conditions. According to RCBD, in total 27 pots were used in this experiment. The experiment area was divided into three equal blocks and each block was covered by 9 pots. The distance between two blocks and two pots were 0.75 m and 0.4 m, respectively.

3.3.4.1 Treatments of experiment

Treatments were as follows:

Factor A: Eggplant varieties (Three)

V_1 = BARI begun-5

V_2 = BARI begun-7

V_3 = Purple king

Factor B:

T_1 = control as normal irrigation

T_2 = Drought stress for 8 days

T_3 = waterlogging stress for 8 days

In this study, there were 9 (3 x 3) treatment combinations such as T_1V_1, T_1V_2, T_1V_3, T_2V_1, T_2V_2, T_2V_3, T_3V_1, T_3V_2 and T_3V_3.

3.3.4.2 Application of treatments

Three eggplant varieties were treated under drought and waterlogged condition. The plants were subjected to the drought and waterlogging at the flowering stage (45 DAT). During the study, the day temperature varied between 25 and 28°C, whereas the night temperature was between 14 and 18°C. The relative humidity (RH) ranged from 45 to 65 percent at its highest and lowest points.

The plants were divided into three groups at the flowering stage. One group (9 pots) of the potted plants were subjected to the waterlogging by submerging them in the water basin (tank) filled with the tap water. The water level was maintained at 1 inch above the pot soil surface. Water height in the tank was 20 cm from the bottom up to the pot soil surface. The waterlogging was imposed for a period of 8 days (45 to 53 DAT). At the end of this period, the pots were removed from the tank and were allowed to recover. The second set (9 pots) of plants was subjected to the drought by withholding the irrigation for a period of 8 days (45 to 53 DAT). The soil moisture during the drought stress was measured using the soil moisture meter (PMS-714). The soil moisture was recorded 9 to 11% at the time of releasing the drought stress. The third group of plants (9 pots) were grown under normal condition as the control.

Plate 3. Application of Drought and waterlogging condition

3.4 Intercultural operations

3.4.1 Weeding and tagging

Weeding was done for all pots when required, to keep the plant free from weeds, diseases and pests that can be a major factor to limiting eggplant production. Plants were irrigated regularly, and recommended practices were followed. According to the treatments plants were tagged 30 DAT by using card.

3.4.2 Application of insecticides

Experimental eggplant plants were treated with Dithane M45 @ 0.5 ml/L and 2 gm/L to prevent unwanted disease problems. Leaf feeder is one of the important pests during the growing stage. Leaf feeder was controlled by Tufgor @ 1.5 ml/L. Those fungicides and insecticide were sprayed two times, first at vegetatively growing stage and next to early flowering stage to manage diseases and pests.

3.5 Harvesting of fruits

Harvesting was done after the fruits reached at the maturity stage. Eggplant fruits were harvested when they attained full maturity indicating a deep violet in color and a hard in consistency. Harvesting was started at 85 DAT (19 March, 2020) and was continued until 100 DAT (5April, 2020).

3.6 Data collections

Data was recorded to address the set objectives, which included plant height, branch number, leaf number, chlorophyll content, flower number, fruit number, fruit weight, fruit length, fruit diameter and yield per pot.

3.6.1 Plant height (cm)

Plant height of each plant of each pot was measured in cm by using meter scale at 65 DAT and 80 DAT and the mean was calculated. The height was measured from base to tip of the plant.

3.6.2 Branch number

Branch number of each plant planted in each pot was counted at 65 DAT and 80 DAT.

3.6.3 Leaf number

Leaf number of each plant planted in each pot was counted at 65 DAT and 80 DAT.

3.6.4 SPAD Value

Leaf chlorophyll content in terms of SPAD (soil plant analysis development) values was recorded using a portable SPAD 502 Plus meter (Konica-Minolta, Tokyo, Japan). In each measurement, the SPAD reading was repeated three times from the leaf tip to base, and the average was used for analysis. Figure 3.3 shows the SPAD meter.

3.6.5 Flower number

The number of flowers per plant was counted and recorded from 75 to 85 DAT.

3.6.6 Fruit number

The number of fruits per plant was counted and recorded from 85 to 100 DAT.

3.6.7 Fruit weight (gm)

Fruit weight was measured by electric precision balance in gram. Total fruit weight of each pot was obtained by adding the weight of total fruits produced and average fruit weight was obtained from division of the total fruit weight by total number of fruits.

Plate 4. SPAD value measurement

3.6.8 Fruit length (cm)

Fruit length was measured in cm with a scale from the neck of the fruit to the bottom and average was calculated.

3.6.9 Fruit diameter (mm)

Diameter of fruit was measured in mm at the middle portion of the selected marketable fruit from each plant with a slide caliper and their average was calculated.

3.6.10 Yield per pot (kg/pot)

Yield per pot was recorded by the summation of all harvested fruit weight per plant (each pot contains one plant) and finally data were recorded in kilogram (kg).

3.7 Data analysis

Collected data was statistically analyzed using Statistix 10 software. Mean for every treatment was calculated and analysis of variance and difference between treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

This chapter discusses the collected experimental results, data analysis, and explanations of such results. Following the research questions, purpose statement, and methodology of this study, it was constructed to represent the important findings. Graphical presentations have been carried out to show the impacts of both drought and waterlogging conditions on the morphological, physiological, and yield performances of the eggplant. Furthermore, the statistical analysis has performed in this chapter to investigate the parametric significance on the outputs.

4.1 Analysis on morphological and physiological findings

4.1.1 Parametric significance on plant height

The parameters such as treatment (drought, waterlogging, and control) and variety (BARI Begun-5, BARI Begun-7, and Purple king) which were statistically significant for the responses were determined using analysis of variance (ANOVA). To be the significant for the responses, p value of the related parameter must be lower than 0.05. The ratio of the standard deviation to the mean is defined as the coefficient of variation (CV). A low CV value represents a high precision in the estimation (Majid *et al*., 2020). Table 3 provides information on ANOVA results of plant height at 65 days.

Table 3. ANOVA results of plant height at 65 days

Factors	DF	SS	MS	F	P
Rep	2	8.332	4.166		
Variety	2	439.843	219.921	322.58	0.0001
Treat	2	56.17	28.085	41.19	0.0001
Variety*Treat	4	8.579	2.145	3.15	0.0436
Error	16	10.908	0.682		
Total	26	523.832			
CV			2.72%		

From Table 3, variety (0.0001) followed by treatment (0.0001) affect the plant height significantly since P values of them were lower than 0.05. The interaction between variety and treatment has p value (0.0436) lower than 0.05, which indicates its significance on plant height as well. Variety (322.58) contributes more to plant height rather than treatment (41.19) and their interaction (3.15) because of having more F value. A low CV value of 2.72% presented a precise analysis of the parameters for plant height at 65 days. Table 4 presents ANOVA results of plant height at 80 days.

Table 4. ANOVA results of plant height at 80 days

Factors	DF	SS	MS	F	P
Rep	2	0.892	0.446		
Variety	2	533.559	266.779	237.65	0.0001
Treat	2	177.956	88.978	79.26	0.0001
Variety*Treat	4	22.304	5.576	4.97	0.0085
Error	16	17.961	1.123		
Total	26	752.672			
CV			3.20%		

From Table 4, variety (0.0001) followed by treatment (0.0001) affected the plant height significantly since P values of them were lower than 0.05. Their interaction has p value (0.0085) lowering than 0.05, which indicates its significance on plant height as well. Variety (237.65) contributes more to plant height rather than treatment (79.26) and their interaction (4.97) because of having more F value. A low CV value of 3.20% yields a precise analysis of the parameters for plant height at 80 days.

4.1.2 Effects of variety and treatment on plant height

4.1.2.1 Effects of treatment conditions on plant height

Figure 6(a-c) showed the influence of treatments (T1 = control, T2 = drought, and T3 = waterlogging) on plant height at 65 and 80 days. Overall, the control (T1) showed the highest plant height, whereas the waterlogging condition (T3) provided the lowest plant height for all the varieties. In Figure 6(a), at 65 days and for V1 (BARI Begun-5), the control condition provided the highest plant height of 28.4 cm, which decreased to 23.15 cm while applying waterlogging condition. This occurred because the waterlogging condition prevented the root respiration and photosynthesis, which affected growth of the eggplant (Jiawei *et al*., 2021). The drought condition showed comparatively higher plant height (25.6 cm) than the waterlogging condition due to a decrease in both the number of plant cells and stomatal conductance (Jaleel *et al*., 2013 and Rizky *et al*., 2017).

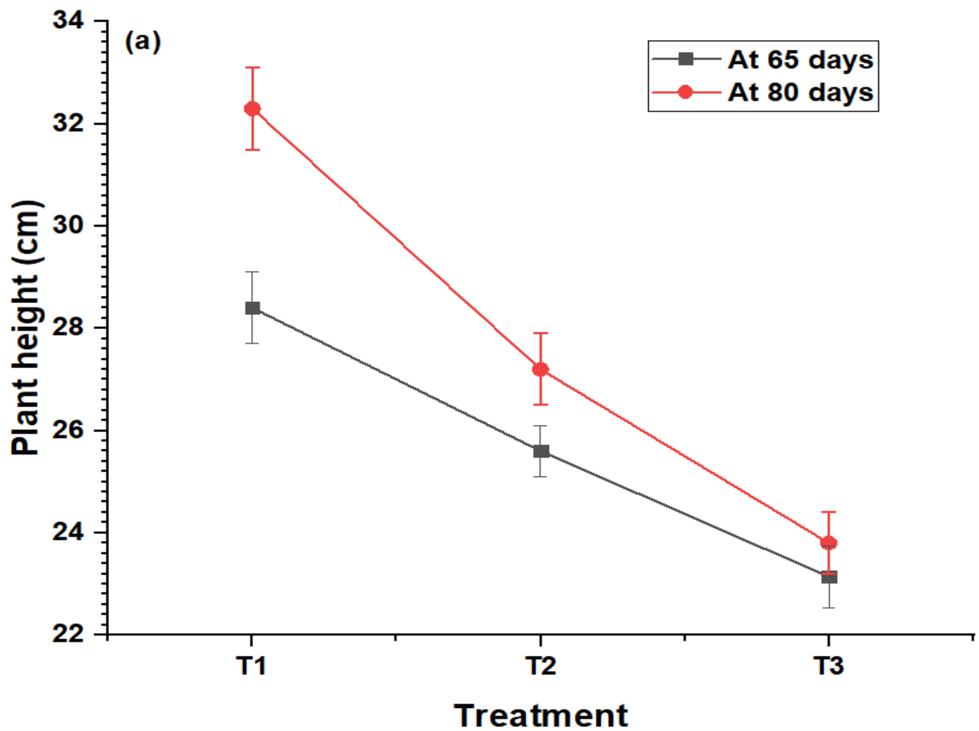

Figure 6(a). Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on plant height at 65 and 80 days for (a) V1 (BARI begun-5) with error bars

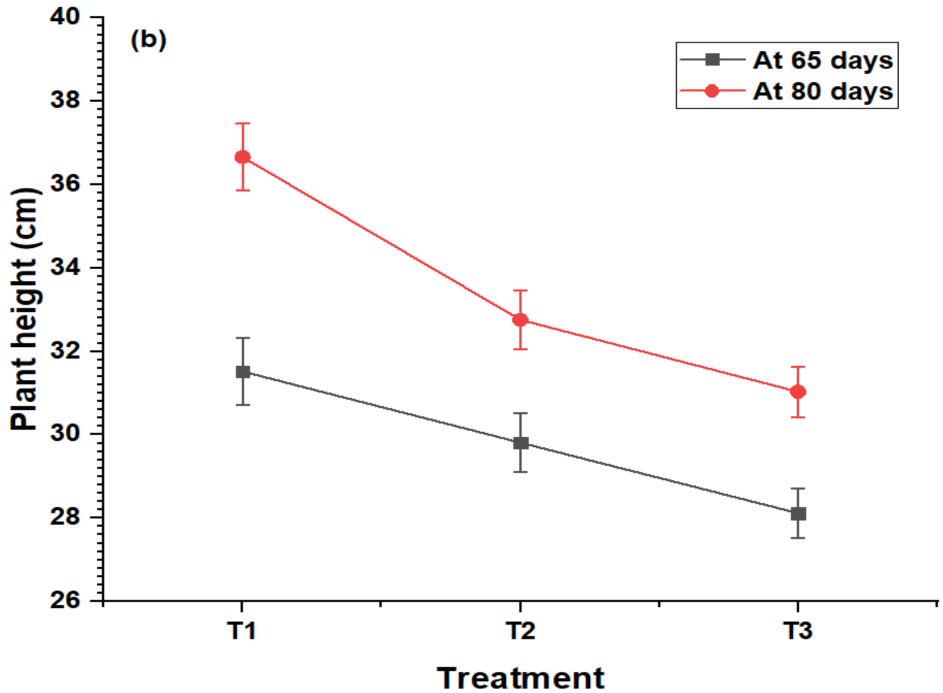

Figure 6(b). Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on plant height at 65 and 80 days for (b) V2 (BARI begun-7) with error bars

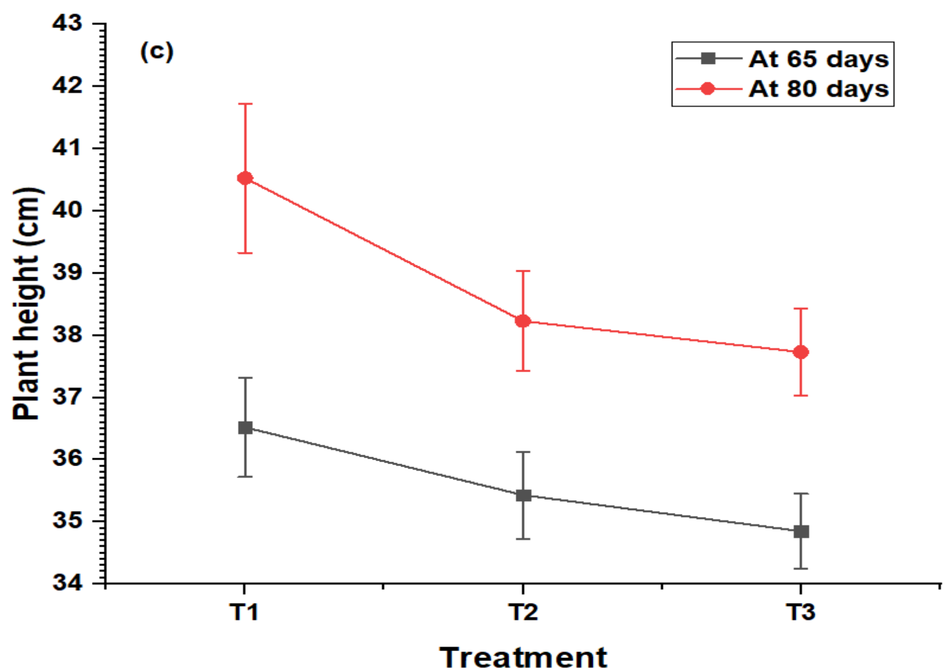

Figure 6(c). Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on plant height at 65 and 80 days for (c) V3 (Purple king) with error bars

At 80 days and for V1, a high plant height of 32.3 cm was observed for control while the plant heights of 27.2 cm and 23.8 cm were found for drought and waterlogging conditions, respectively. From Figure 6(b), at 65 days and for V2 (BARI Begun-7), the control condition showed the largest plant height of 31.52 cm, which reduced to 29.81 cm and 28.12 cm, respectively while applying drought and waterlogging conditions, respectively. At 80 days and for V2, a plant height of 36.66 cm was observed for control while the plant heights of 32.76 cm and 31.03 cm were found for drought and waterlogging conditions, respectively. In Figure 6(c), at 65 days and for V3 (Purple king), the control condition revealed the highest plant height of 36.52 cm, which decreased to 34.85 cm while applying the waterlogging condition. The drought condition showed comparatively higher plant height (35.43 cm) than the waterlogging condition. At 80 days and for V3, a high plant height of 40.53 cm was observed for control while the plant heights of 38.23 cm and 37.73 cm, respectively were found for drought and waterlogging conditions, respectively.

4.1.2.2 Effects of variety on plant height

Figure 7 shows the effects of variety on plant height at 65 days.

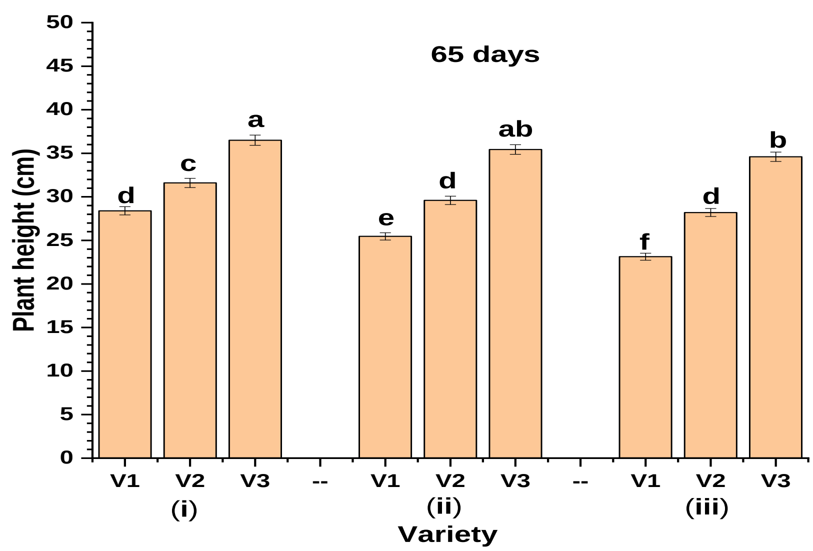

Figure 7. Influence of varieties (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on plant height at 65 days for (i) T1 (control), (ii) T2 (drought) and (iii) T3 (waterlogging) with error bars

Overall, V3 (Purple king) showed the highest plant height, whereas V1 (BARI Begun-5) reveals the smallest plant height at any treatment condition. From Figure 7, at 65 days, the highest plant height of 36.5 cm was observed for V3 and T1, whereas the lowest plant height of 23.13 cm was found for V1 and T3. V1 showed a high plant height of 28.4 cm when T1 was applied. A plant height of 28.2 cm was recorded for V2 and T3, which increased to 31.6 cm for V2 and T1. Figure 8 shows the effects of variety on plant height at 80 days. Overall, V3 (Purple king) showed the highest plant height, whereas V1 (BARI Begun-5) revealed the smallest plant height at different treatment conditions. In Figure 8, at 80 days, the largest plant height of 40.56 cm was observed for V3 and T1 while the smallest plant height of 23.4 cm was found for V1 and T3. V1 showed a high plant height of 32.36 cm when T1 was applied. A plant height of 30.33 cm was recorded for V2 and T3, which increased to 36.6 cm for V2 and T1.

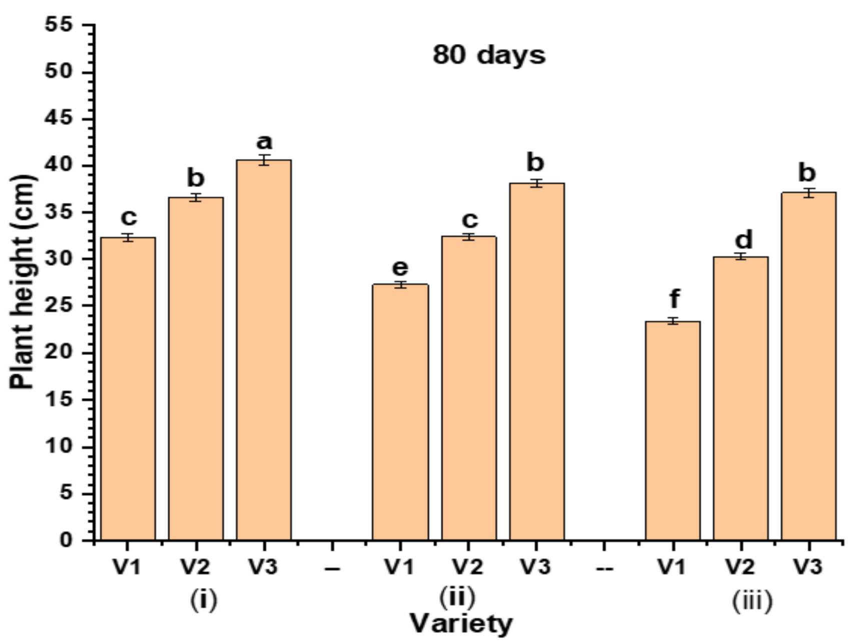

Figure 8. Influence of varieties (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on plant height at 80 days for (i) T1 (control), (ii) T2 (drought) and (iii) T3 (waterlogging) with error bars

It was concluded that the waterlogging condition (T3) affected the plant height of all the varieties most. Moreover, in term of plant height, V1 (BARI Begun-5) was affected by the treatment most while V3 (Purple king) was influenced by the treatment least.

Hussein *et al*. (2007) and Ilahi *et al*. (2018) reported that eggplant varieties are affected by drought stress and resulted a reduced plant height due to altered stomatal mechanism. Lisar *et al*. (2012 reported that drought stress condition interferes plant physiological activities and causes gradual decrease of plant height. Singh *et al.*, 1995 found drought reduce chickpea plant height. Similar type of result also reported by Hossain, 2011 in mungbean. Waterlogging resulted in morphological variation as reduced plant height in eggplant due to altered physiological event like reduced cell growth (Senyigit *et al*., 2011). Inhibiting gas exchange within the root zone under waterlogging condition has the potential to harm roots, limiting the plant's ability to absorb water and nutrients (Belford *et al*., 1992) which ultimately resulted a stunted growth in eggplant. Loreti *et al*. (2016) reported also similar result under waterlogging stress in a variety of plants, such as tomato, pea and wheat.

4.1.3 Parametric significance on branch number

Table 5 provides information on ANOVA results of branch number at 65 days.

Table 5. ANOVA results of branch number at 65 days

Factors	DF	SS	MS	F	P
Rep	2	5.407	2.703		
Variety	2	24.518	12.259	75.66	0.0001
Treat	2	12.518	6.259	38.63	0.0001
Variety*Treat	4	1.481	0.37	2.29	0.1051
Error	16	2.5926	0.162		
Total	26	46.518			
CV			3.67%		

From Table 5, variety (0.0001) followed by treatment (0.0001) affected the branch number significantly since P values of them were lower than 0.05. The interaction between variety and treatment has p value (0.1051) higher than 0.05, which indicates it has no significance on branch number. Variety (75.66) contributed more to branch number rather than treatment (38.63) because of having more F value. A low CV value of 3.67% presented a precise analysis of the parameters for the branch number at 65 days. Table 6 presents ANOVA results of branch number at 80 days.

Table 6. ANOVA results of branch number at 80 days

Factors	DF	SS	MS	F	P
Rep	2	3.851	1.925		
Variety	2	39.407	19.703	42.14	0.0001
Treat	2	20.518	10.259	21.94	0.0001
Variety*Treat	4	5.481	1.37	2.93	0.054
Error	16	7.481	0.467		
Total	26	76.74			
CV			4.73%		

From Table 6, variety (0.0001) followed by treatment (0.0001) affected the branch number significantly since P values of them were lower than 0.05. Their interaction has p value (0.054) higher than 0.05, which indicates it has no significance on branch number. A low CV value of 4.73% yields a precise analysis of the parameters for branch number at 80 days.

4.1.4 Effects of variety and treatment on branch number

4.1.4.1 Effects of treatment conditions on branch number

Figure 9(a-c) showed the influence of treatment (T1 = control, T2 = drought, and T3 = waterlogging) on branch number at 65 and 80 days. Overall, the control (T1) showed the highest branch number, whereas the waterlogging condition (T3) provided the lowest branch number for all the varieties. In Figure 9(a), at 65 days and for V1 (BARI Begun-5), the highest branch number of 4 was obtained at T1 condition, which was reduced to 3 at both T2 (drought) and T3 (waterlogging) conditions. At 80 days and for V1, a high branch number of 6 was observed for control while branch number of 4 was found for both drought and waterlogging conditions. From Figure 9(b), at 65 days and for V2 (BARI Begun-7), both the control and drought conditions yielded a high branch number of 6, which reduced to 4 while applying waterlogging condition.

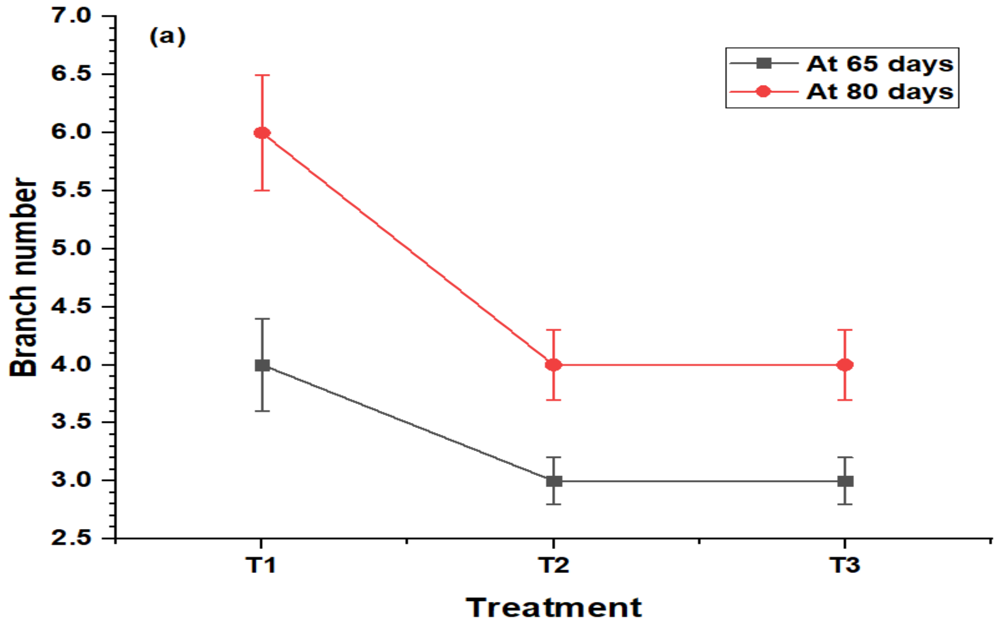

Figure 9(a). Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on branch number at 65 and 80 days for (a) V1 (BARI begun-5) with error bars

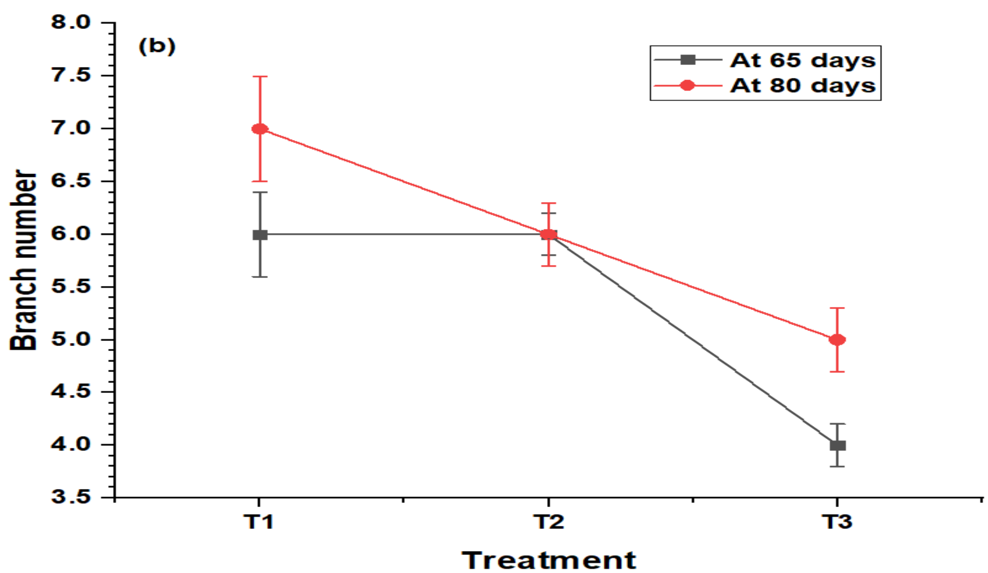

Figure 9(b). Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on branch number at 65 and 80 days for (b) V2 (BARI begun-7) with error bars

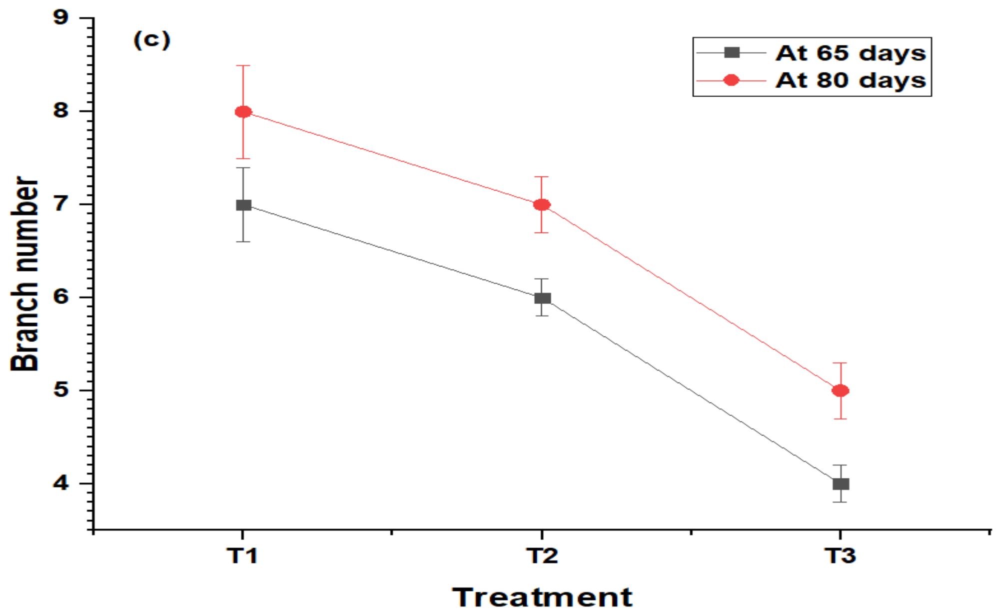

Figure 9(c). Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on branch number at 65 and 80 days for (c) V3 (Purple King) with error bars

At 80 days and for V2, a high branch number of 7 was observed for control while branch number of 6 and 5, respectively were found for drought and waterlogging conditions, respectively. In Figure 9(c), at 65 days and for V3 (Purple king), the control condition revealed the highest branch number of 7, which decreased sharply to 4 while applying the waterlogging condition. The drought condition showed comparatively higher branch number of 6 than the waterlogging condition. At 80 days and for V3, a high branch number of 8 is observed for control while branch number of 7 and 5, respectively were found for drought and waterlogging conditions, respectively.

4.1.4.2 Effects of variety on branch number

Figure 10(a-c) shows the effects of variety on branch number at 65 and 80 days.

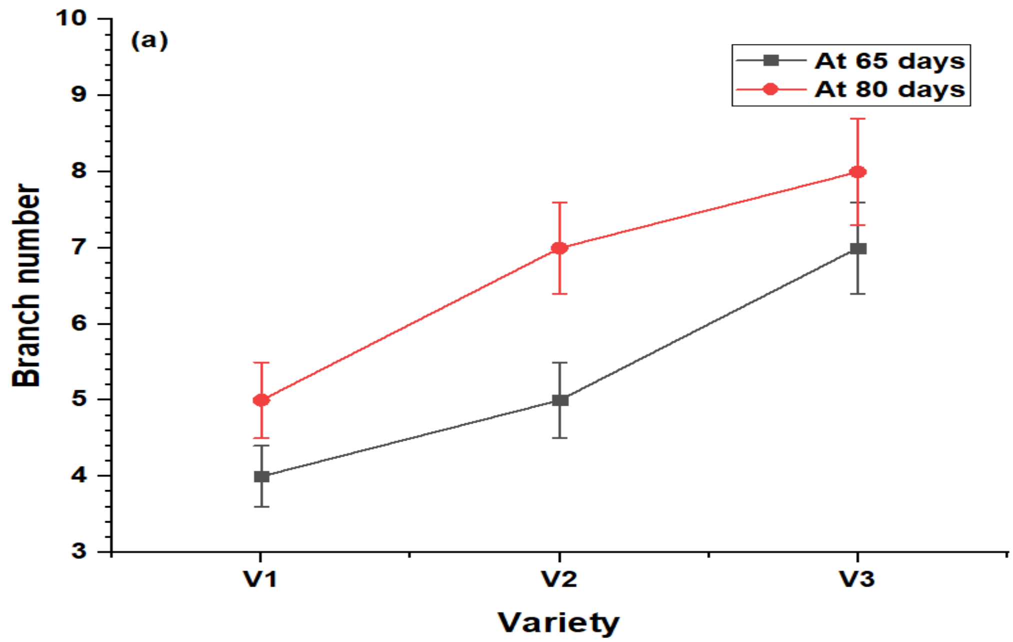

Figure 10(a). Influence of varieties (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on branch number at 65 and 80 days for (a) T1 (control) with error bars

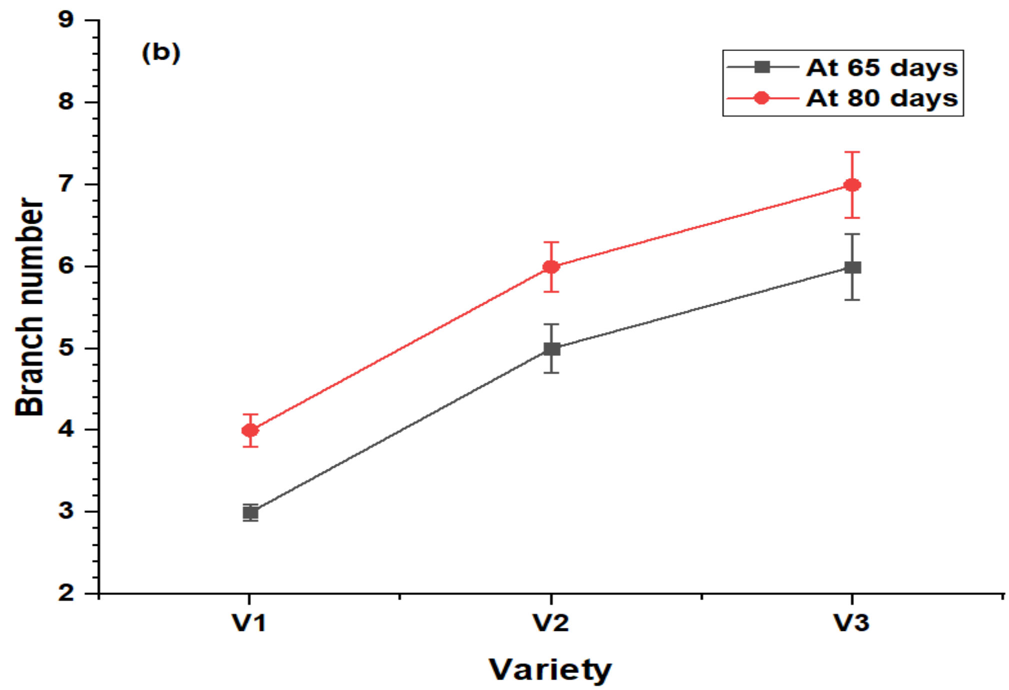

Figure 10(b). Influence of varieties (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on branch number at 65 and 80 days for (b) T2 (drought) with error bars

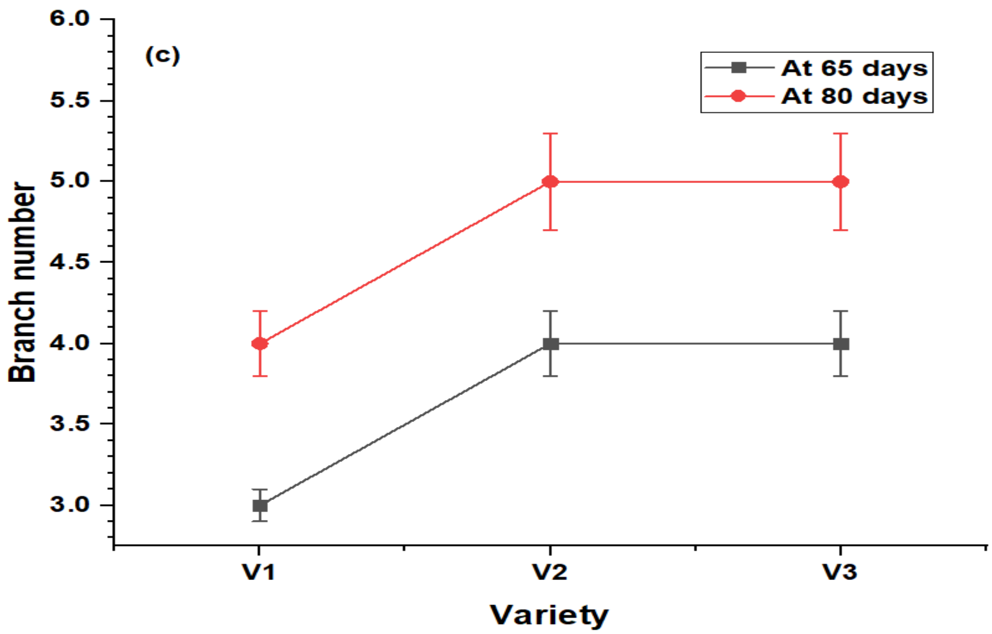

Figure 10(c). Influence of varieties (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on branch number at 65 and 80 days for (c) T3 (waterlogging) with error bars

Overall, V3 (Purple king) showed the highest branch number, whereas V1 (BARI Begun-5) provided the lowest branch number at different treatment conditions. In Figure 10(a), at 65 days and for T1 (control), the highest branch number of 7 was obtained for V3, which was declined to 5 and 4 for V2 and V1, respectively. At 80 days and for T1, a high branch number of 8 were observed for V3 while branch number of 7 and 5 were found for V2 and V1, respectively. From Figure 10(b), at 65 days and for T2 (drought), V3 showed a high branch number of 6, which reduced to 5 and 3 while selecting V2 and V1, respectively. At 80 days and for T2, a high branch number of 7 were observed for V3 while branch number of 6 and 4 were found for V2 and V1, respectively. In Figure 10(c), at 65 days and for T3 (waterlogging), both V3 and V2 revealed the highest branch number of 4, which decreased to 3 for V1. At 80 days and for T3, both V3 and V2 revealed the highest branch number of 5, which decreased to 4 for V1.

It was concluded that the waterlogging condition (T3) affected branch number of all the varieties most. Moreover, in term of branch number, V1 (BARI Begun-5) was affected by the treatments (drought and waterlogging) most while V3 (Purple king) was influenced by the treatments least.

As water stress intensified, the number of branches per plant reduced in eggplant (Ilahi *et al*., 2018). Drought stress induced similar findings have also been reported in tomato (Pervez *et al*., 2009), Okra (Kusvuran, 2012) and bottle gourd (Sithole and Modi, 2015) cultivars. Drought stress condition disturbs plant physiological processes which are reflected in low water absorption and ultimately lower vegetative growth (Conti *et al*., 2019, Lisar *et al.*, 2012). Anjum *et al*., 2011 also reported similar result in tomato due to decreased photosynthetic activity under drought stress. Under waterlogging stress poor root development and delayed nitrogen uptake from the anaerobic soil cause chlorosis in older leaves and fewer branch number in eggplant (Belford *et al*., 1992). Similar output reported in *Annona species* (Nunez-Elisea, 1999), *Panicum antidotale* (Ashraf, 2003) and tomato, all showed a reduction in plant growth owing to waterlogging (Walter, 2004; Ezin *et al*., 2010).

4.1.5 Parametric significance on leaf number

Table 7 shows information on ANOVA results of leaf number at 65 days.

Table 7. ANOVA results of leaf number at 65 days

Factors	DF	SS	MS	F	P
Rep	2	8.667	4.333		
Variety	2	262.889	131.444	1577.3	0.0001
Treat	2	60.667	30.333	364	0.0001
Variety*Treat	4	4.444	1.111	13.33	0.001
Error	16	1.333	0.083		
Total	26	338			
CV			0.97%		

From Table 7, variety (0.0001) followed by treatment (0.0001) affected the leaf number significantly since P values of them eare lower than 0.05. The interaction between variety and treatment has p value (0.0436), lower than 0.05, which indicated its significance on leaf number as well. Variety (1577.3) contributed more to leaf number rather than treatment (364) and their interaction (13.33) because of having more F value. A very low CV value of 0.97% presented a precise analysis of the parameters for leaf number at 65 days. Table 8 presents ANOVA results of leaf number at 80 days.

Table 8. ANOVA results of leaf number at 80 days

Factors	DF	SS	MS	F	P
Rep	2	4.963	2.481		
Variety	2	545.407	272.704	1178.1	0.0001
Treat	2	138.963	69.481	300.16	0.0001
Variety*Treat	4	5.037	1.259	5.44	0.0058
Error	16	3.704	0.231		
Total	26	698.074			
CV			1.37%		

From Table 8, variety (0.0001) followed by treatment (0.0001) affected leaf number significantly since P values of them were lower than 0.05. Their interaction has p value (0.0058), lower than 0.05, which indicated its significance on leaf number as well. Variety (1178.1) contributed more to leaf number rather than treatment (300.16) and their interaction (5.44) because of having more F value. A low CV value of 1.37% yielded a precise analysis of the parameters for leaf number at 80 days.

4.1.6 Effects of variety and treatment on leaf number

4.1.6.1 Effects of treatment conditions on leaf number

Figure 11(a-c) shows the influence of treatments on leaf number at 65 and 80 days. Overall, T1 showed the highest leaf number, whereas T3 provided the lowest leaf number for the selected varieties. In Figure 11(a), at 65 days and for V1, T1 provided the highest leaf number of 29, which decreased to 24 while applying T3. T2 showed comparatively higher leaf number of 26 than T3 condition. At 80 days and for V1, a high leaf number of 34 was observed for T1 while leaf number of 31 and 28 were found for T2 and T3 condition, respectively. From Figure 11(b), at 65 days and for V2, T1 yielded the largest leaf number of 30, which reduced to 28 and 27 while applying T2 and T3 conditions, respectively. At 80 days and for V2, a leaf number of 36 was observed for T1 while leaf number of 34 and 32 were found for drought (T2) and waterlogging (T3) conditions, respectively. In Figure 11(c), at 65 days and for V3, T1 revealed the highest leaf number of 35, which decreased to 32 while applying the waterlogging condition. The drought condition (T2) showed comparatively higher leaf number of 34 than the waterlogging condition. At 80 days and for V3, a high leaf number of 43 was observed for T1 while leaf number of 41 and 37 were found for drought and waterlogging conditions, respectively.

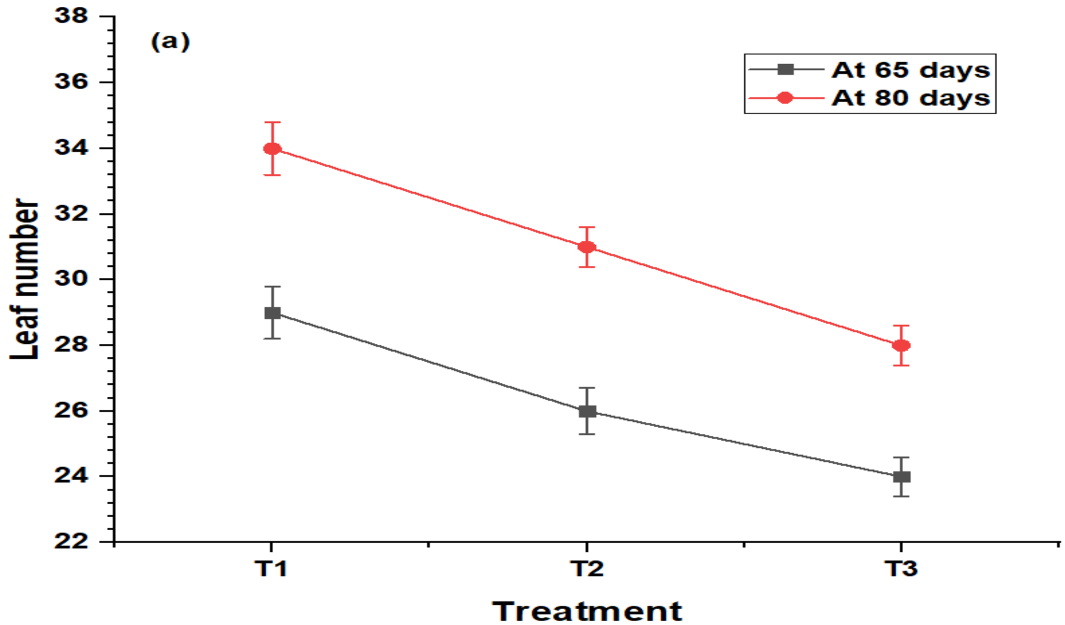

Figure 11(a). Influences of treatments (T1 = control, T2 = drought and T3 = waterlogging) on leaf number at 65 and 80 days for (a) V1 (BARI begun-5) with error bars

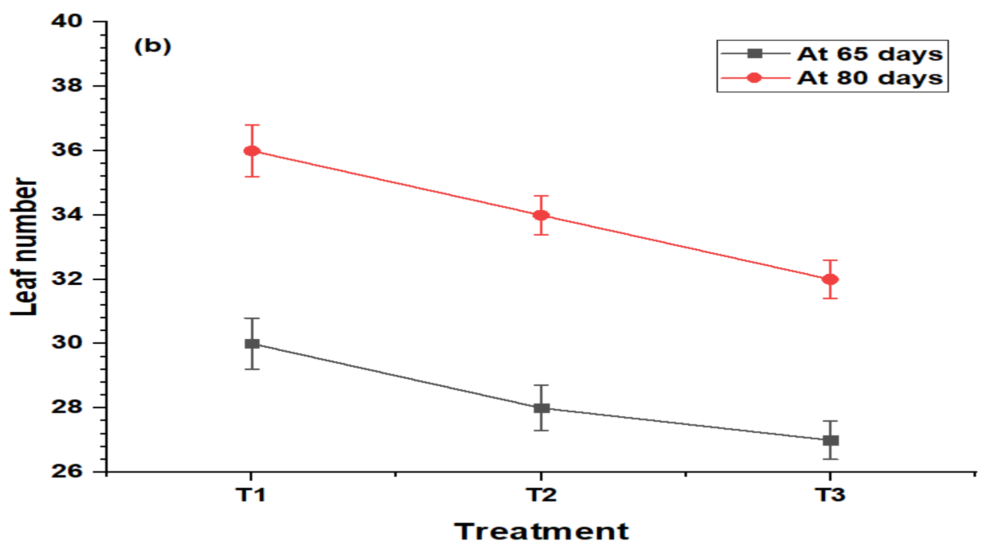

Figure 11(b). Influences of treatments (T1 = control, T2 = drought and T3 = waterlogging) on leaf number at 65 and 80 days for (b) V2 (BARI begun-7) with error bars

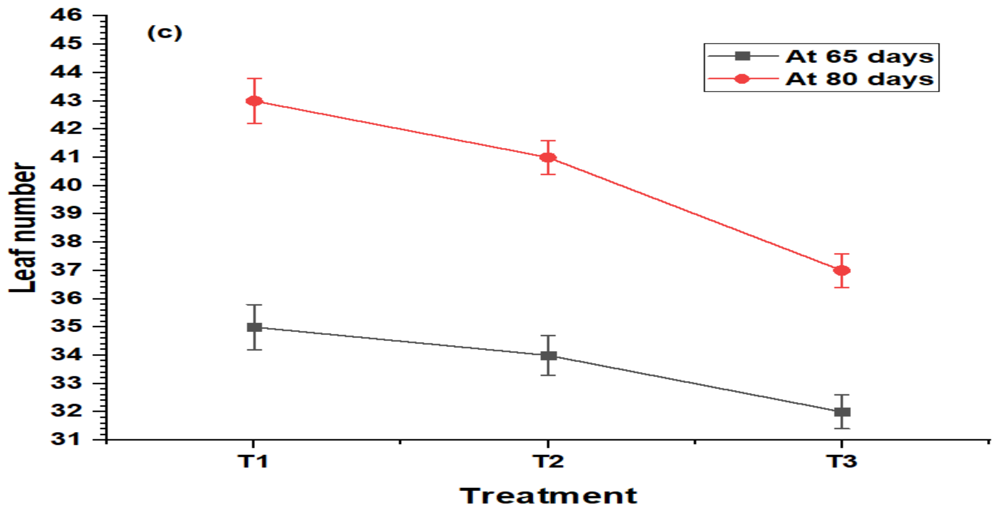

Figure 11(c). Influences of treatments (T1 = control, T2 = drought and T3 = waterlogging) on leaf number at 65 and 80 days (c) V3 (Purple king) with error bars

4.1.6.2 Effects of variety on leaf number

Figure 12 shows the effects of variety on leaf number at 65 and 80 days. Overall, V3 (Purple king) showed the highest leaf number, whereas V1 (BARI Begun-5) provided the lowest leaf number at different treatment conditions. In Figure 12(a), at 65 days and for T1 (control), the highest leaf number of 35 was obtained for V3, which was declined to 30 and 29 for V2 and V1, respectively. At 80 days and for T1, a high leaf number of 44 was observed for V3 while leaf number of 36 and 34 were found for V2 and V1, respectively. From Figure 12(b), at 65 days and for T2 (drought), V3 showed a high leaf number of 34, which reduced to 28 and 26 while selecting V2 and V1, respectively. At 80 days and for T2, a high leaf number of 42 was observed for V3 while leaf number of 34 and 30 were found for V2 and V1, respectively. In Figure 12(c), at 65 days and for T3 (waterlogging), V3 revealed the highest leaf number of 32, which decreased to 27 and 24 for V2 and V1, respectively. At 80 days and for T3, V3 showed the highest leaf number of 39, which decreased to 32 and 27 for V2 and V1, respectively.

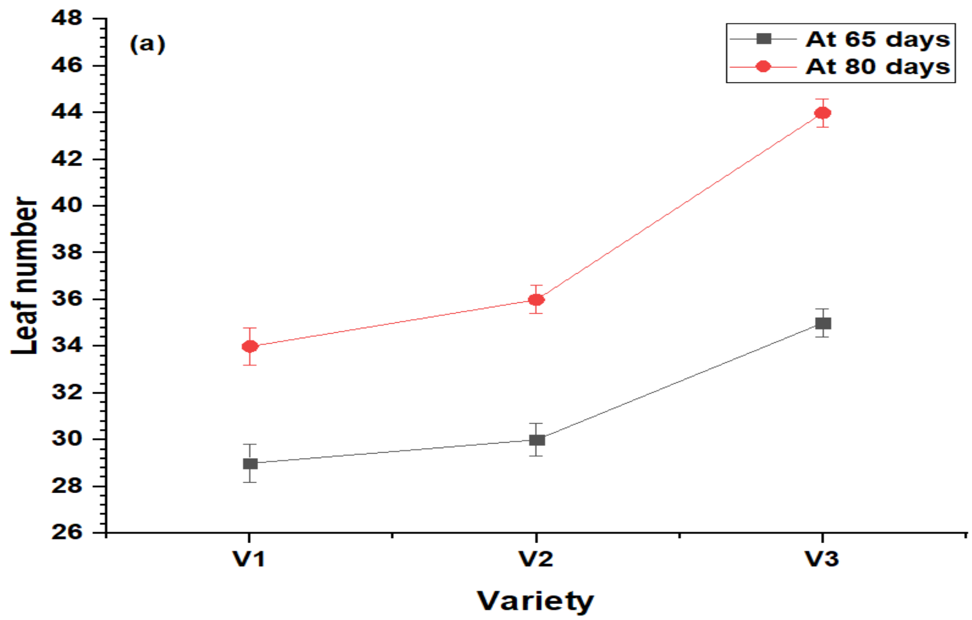

Figure 12(a). Influence of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on leaf number at 65 and 80 days for (a) T1 (control) with error bars

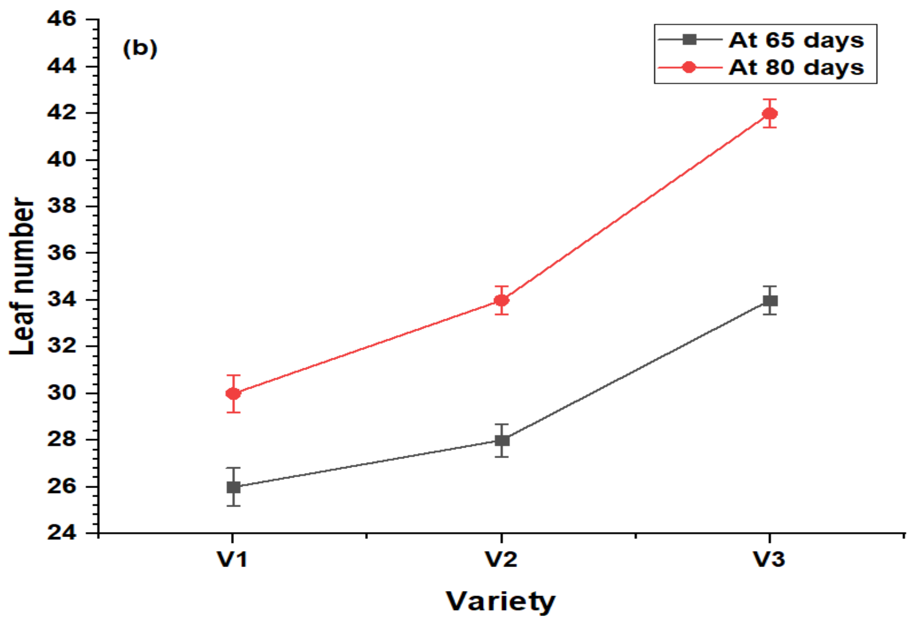

Figure 12(b). Influence of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on leaf number at 65 and 80 days for (b) T2 (drought) with error bars

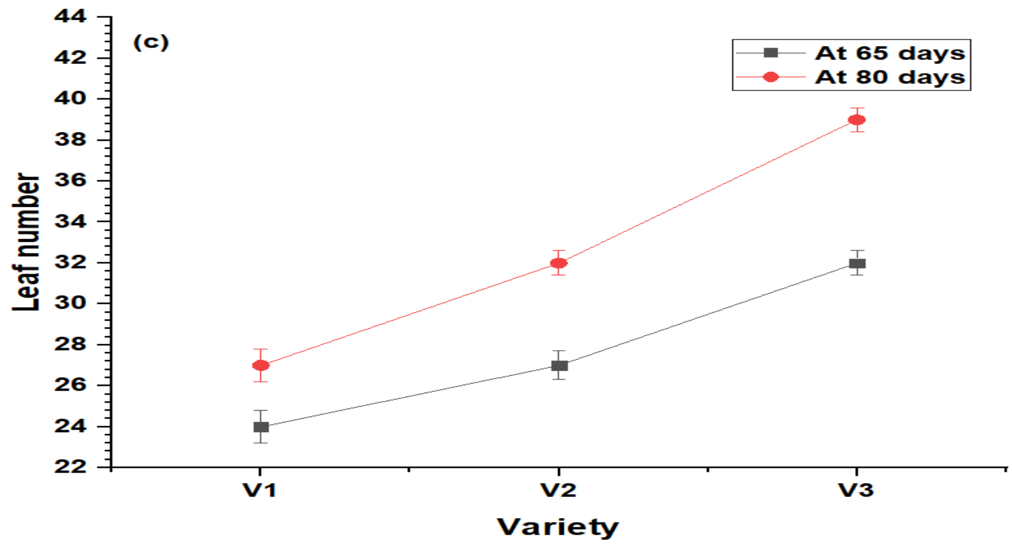

Figure 12(c). Influence of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on leaf number at 65 and 80 days for (c) T3 (waterlogging) with error bars

It is concluded that the waterlogging condition (T3) affected leaf number of all the varieties most. Moreover, in term of leaf number, V1 (BARI Begun-5) was affected by the treatments (drought and waterlogging) most while V3 (Purple king) was influenced by the treatments least.

Water stress causes reduced leaf number in eggplant due to a decrease in cell expansion and increased leaf senescence (Manivannan *et al*., 2007a). Ilahi *et al. (*2018) also reported decreased number of leaves in eggplant under drought stress. Similar results found in maize (Anjum *et al*., 2011a) and bitter gourd (Shahbaz *et al*., 2015) under drought stress. By reducing the soil's water potential, water deficiencies lower the number of leaves per plant and individual leaf size, as well as leaf longevity (Zhao *et al*., 2006). Because of altered physiological processes, the impacts of waterlogging on winter crops, including eggplant, are frequently seen as lower number of leaves and chlorosis of older leaves (Ellington, 1986). Solaiman *et al*. (2007) also reported similar result in case of lentils and chickpea due to reduced photosynthetic activities.

4.1.7 Parametric significance on SPAD Value

Table 9 shows data on ANOVA results of SPAD value at 67 days.

Table 9. ANOVA results of SPAD value at 67 days

Factors	DF	SS	MS	F	P
Rep	2	4.97	2.485		
Variety	2	241.116	120.558	174.56	0.0001
Treat	2	85.716	42.858	62.05	0.0001
Variety*Treat	4	8.728	2.182	3.16	0.043
Error	16	11.05	0.691		
Total	26	351.581			
CV			1.58%		

From Table 9, variety (0.0001) followed by treatment (0.0001) affected the SPAD value significantly since P values of them were lower than 0.05. The interaction between variety and treatment has p value (0.043), lower than 0.05, which indicated its significance on SPAD values as well. Variety (174.56) contributed more to SPAD value rather than treatment (62.05) and their interaction (3.16) because of having more F value.

A very low CV value of 1.58% yielded a precise analysis of the parameters for SPAD value at 67 days. Table 10 presents ANOVA results of SPAD value at 80 days.

Table 10. ANOVA results of SPAD value at 80 days

Factors	DF	SS	MS	F	P
Rep	2	4.01	2.005		
Variety	2	543.41	271.705	570.73	0.0001
Treat	2	140.592	70.296	147.66	0.0001
Variety*Treat	4	19.77	4.943	10.38	0.002
Error	16	7.617	0.476		
Total	26	715.399			
CV			1.21%		

From Table 10, variety (0.0001) followed by treatment (0.0001) affected SPAD value significantly since P values of them were lower than 0.05. Their interaction has p value (0.002), lower than 0.05, which indicated its significance on SPAD value. Variety (570.73) contributed more to SPAD value rather than treatment (147.66) and their interaction (10.38) because of having more F value. A low CV value of 1.21% provided a precise analysis of the parameters for SPAD value at 80 days.

4.1.8 Effects of variety and treatment on SPAD value

4.1.8.1 Effects of treatment conditions on SPAD value

Figure 13(a-c) shows the influence of treatments on SPAD value at 67 days. Overall, T1 showed the highest SPAD value, whereas T3 provided the lowest SPAD value for the selected varieties. In Figure 13(a), at 67 days and for V1, T1 provided the highest SPAD value of 51.8, which decreased to 45.2 SPAD value while applying T3. T2 showed comparatively higher SPAD value of 48.4 than T3 condition. From Figure 13(b), at 67 days and for V2, a high SPAD value of 55.3 was observed for T1 while 52.6 and 51.2 SPAD values were found for T2 and T3 condition, respectively. As shown in Figure 13(c), at 67 days and for V3, T1 yielded the highest SPAD value of 57.4, which decreased to 55 SPAD value when T3 was applied. T2 showed slightly higher SPAD value of 55.44 than T3 condition.

Figure 14(a-c)) shows the influence of treatments on SPAD value at 80 days. Overall, a high SPAD value was observed for T1 condition, whereas a low SPAD value was found for T2 followed by T1 at different varieties. From Figure 14(a), at 80 days and for V1, a 55.7 SPAD value was calculated for T1 condition, which reduced to 47.53 SPAD value for T3. In Figure 14(b), at 80 days and for V2, 59.73 SPAD value was obtained for T1 condition, which reduced to 57.23 and 54.23 SPAD value for T2 and T3, respectively. In Figure 14(c), at 80 days and for V3, a SPAD value of 64.3 was measured for T1 condition, which reduced to 62.3 and 61.2 SPAD value for T2 and T3, respectively.

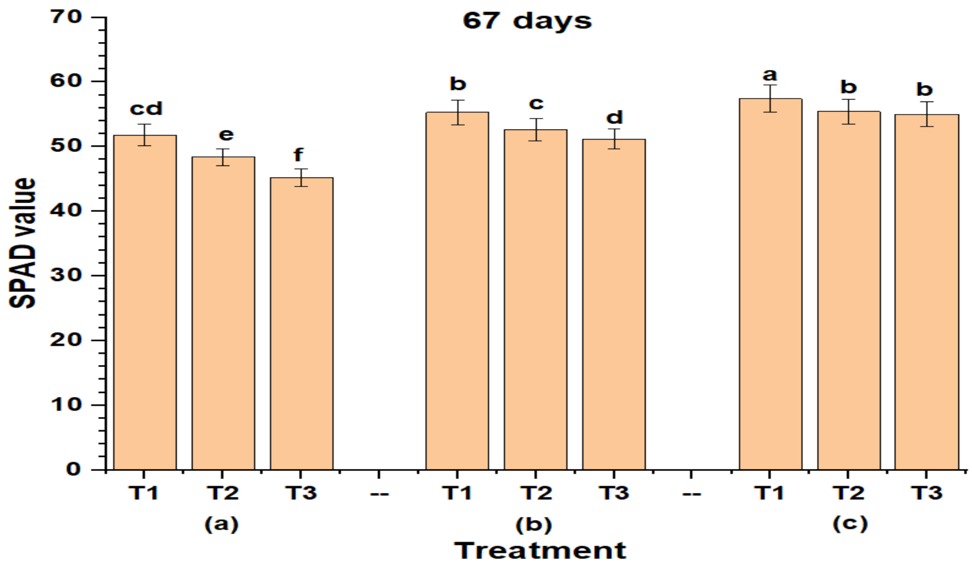

Figure 13. Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on SPAD values at 67 days for (a) V1 (BARI begun-5), (b) V2 (BARI begun-7) and (c) V3 (Purple king) with error bars

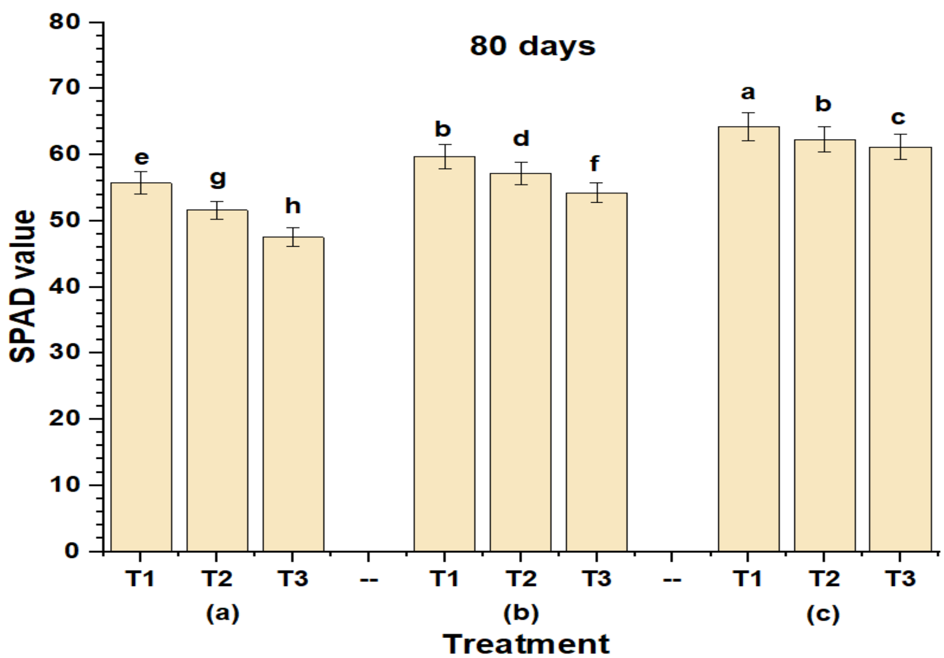

Figure 14. Influence of treatments (T1 = control, T2 = drought and T3 = waterlogging) on SPAD values at 80 days for (a) V1 (BARI begun-5), (b) V2 (BARI begun-7) and (c) V3 (Purple king) with error bars

4.1.8.2 Effects of variety on SPAD value

Figure 15 (i-iii) shows the effects of variety on SPAD value at 67 days. Overall, V3 (Purple king) showed the highest SPAD value, whereas V1 (BARI Begun-5) reveals the lowest SPAD value at different treatment conditions. In Figure 15(i), at 67 days and for T1, V3 provided the highest SPAD value of 57.4, which decreased to 55.2 SPAD value while applying V2. V1 showed comparatively lower SPAD value of 51.6 than V2. From Figure 15(ii), at 67 days and for T2, a high content of 55.4 SPAD value was observed for V3 while 53 SPAD value and 48.8 SPAD value were found for V2 and V1, respectively. As shown in Figure 15(iii), at 67 days and for T3, V3 yielded the highest content of 55.6 SPAD value, which decreased to 51.4 SPAD value when V2 was selected. V1 showed lower content of 45.6 SPAD value than V2. Figure 16 shows the effects of variety on SPAD values at 80 days.

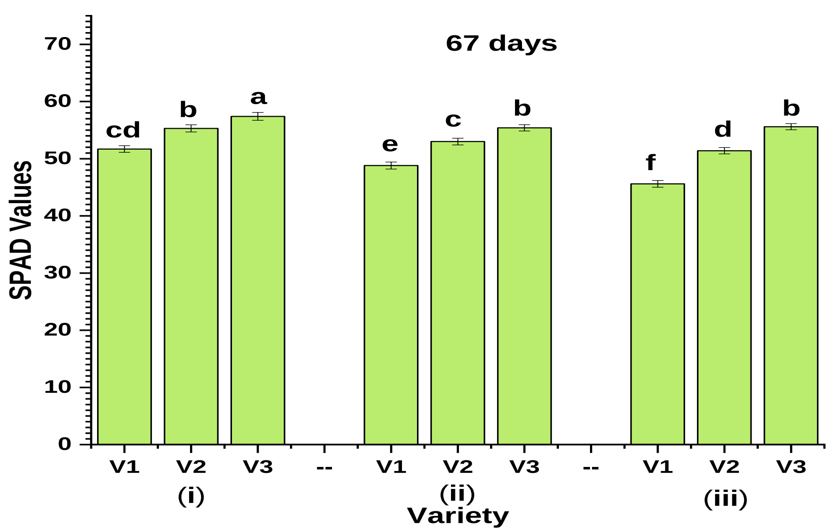

Figure 15. Influence of varieties (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on SPAD values at 67 days for (i) T1 (control), (ii) T2 (drought) and (iii) T3 (waterlogging) with error bars

In Figure 16(i), at 80 days and for T1, V3 provided a high SPAD value of 64.4, which decreased to 55.8 SPAD value while applying V1. V2 showed comparatively higher content of 60 SPAD value than V1. From Figure 16(ii), at 80 days and for T2, a high content of 62.8 SPAD value was observed for V3 while 57.2 and 51.6 SPAD values were found for V2 and V1, respectively. As shown in Figure 16(iii), at 80 days and for T3, V3 yielded the highest content of 61.6 SPAD values, which decreased to 54.8 SPAD values when V2 was selected. V1 showed lower content of 48 SPAD value than V2.

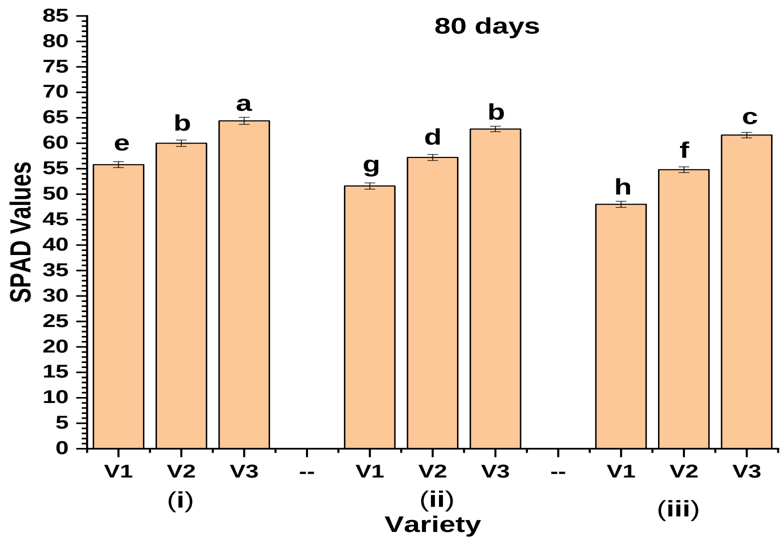

Figure 16. Influence of varieties (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on SPAD values at 80 days for (i) T1 (control), (ii) T2 (drought) and (iii) T3 (waterlogging) with error bars

It is concluded that the waterlogging condition (T3) affected SPAD value of all the varieties more than the drought (T2) condition. Moreover, in term of SPAD value, V1 (BARI Begun-5) was affected by the treatments (drought and waterlogging) most while V3 (Purple king) was influenced by the treatments least.

Drought stress resulted in a significant reduction in SPAD value in eggplants compared to control, according to (Madramootoo and Rigby, 1991) and (Salisbury and Ross, 1992). Manivannan *et al*. (2007b) also reported reduced amount of chlorophyll a, chlorophyll b, and total chlorophyll in many sunflowers. Inalpulat *et al.* (2014) also reported decreased photosynthesis and chlorophyll measurements in eggplant under water stress. Similar findings found in eggplant (Farooq *et al*., 2008) and maize (Anjum *et al.*, 2011a). Loreti *et al*. (2016) reported decreased SPAD values in eggplant under waterlogged condition due to decreased photosynthetic capacity. Similar findings reported in barley, field peas (Bakker *et al.*, 2007; Romina *et al.*, 2018) and chickpeas under waterlogging condition (Solaiman *et al*., 2007).

4.2 Analysis of yield performances of eggplant

4.2.1 Parametric significance on flower number

Table 11 shows data on ANOVA results of flower number. From Table 11, variety (0.0001) followed by treatment (0.0001) impacted flower number significantly since P values of them were lower than 0.05. Their interaction has p value (0.002), lower than 0.05, which indicated its significance on flower number. Variety (216.81) contributed more to flower number rather than treatment (53.31) and their interaction (4.09) because of having more F value. A low CV value of 3.58% provided a precise analysis of the parameters for flower number.

Table 11. ANOVA results of flower number

Factors	DF	SS	MS	F	P
Rep	2	4.519	2.259		
Variety	2	256.963	128.481	216.81	0.0001
Treat	2	63.185	31.593	53.31	0.0001
Variety*Treat	4	9.704	2.426	4.09	0.018
Error	16	9.481	0.593		
Total	26	343.852			
CV			3.58%		

4.2.2 Influences of variety and treatment on flower number

4.2.2.1 Effects of drought and waterlogging condition on flower number

Figure 17 shows the effects of treatment on flower number at flowering stage. Overall, a high flower number was observed for control (T1), whereas a low flower number was noticed for waterlogging (T3) at any variety. At V1, a flower number of 13 was found for T1, which decreased to 9 when T2 was applied. A further decrement of flower number to 8 was observed for T3. At V2, a flower number of 16 was recorded for T1, which reduceed to 13 for T2. Afterward, a sudden increase of flower number (15) was seen for T3. At V3, the highest flower number of 20 was noticed for T1 followed by T2 (19) while the lowest flower number of 17 was found for T3.

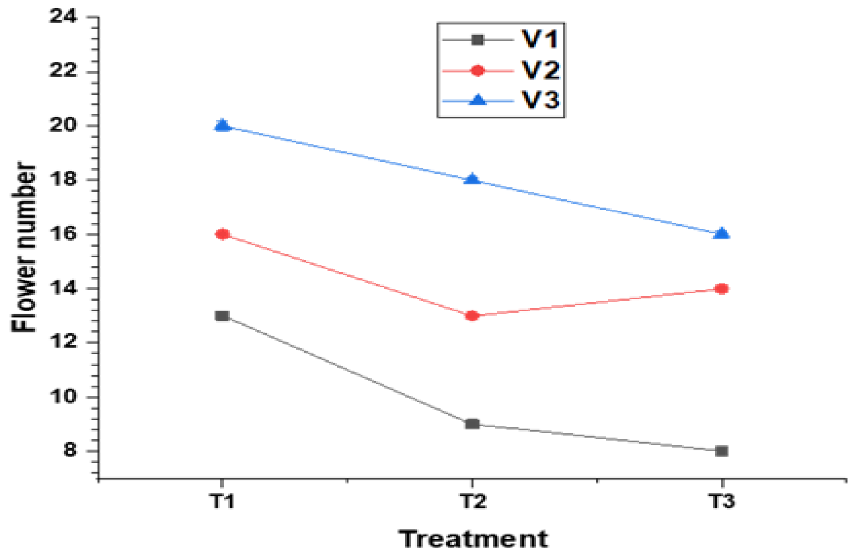

Figure 17. Effects of treatments (T1 = control, T2 = drought and T3 = waterlogging) on flower number at flowering stage with error bars

4.2.2.2 Effects of variety on flower number

Figure 18 shows the effects of variety on flower number at flowering stage. Overall, V3 (Purple king) shows the highest flower number, whereas V1 (BARI Begun-5) revealed the lowest flower number at different treatment conditions. At T1, a high flower number of 20 was found for V3, which was followed by V2, whereas the lowest flower number of 13 was obtained for V1. At T2, a high flower number of 18 was found for V3, which decreased to 13 for V2. Further decline in flower number to 9 was observed for V1. At T3, a high flower number of 16 was found for V3, which was followed by V2, whereas the lowest flower number of 8 was obtained for V1.

It is concluded that application of the waterlogging stress in the variety affected the flower number more compared to drought stress. V3 (Purple king) was not significantly affected by both waterlogging and drought conditions while V1 was affected the most.

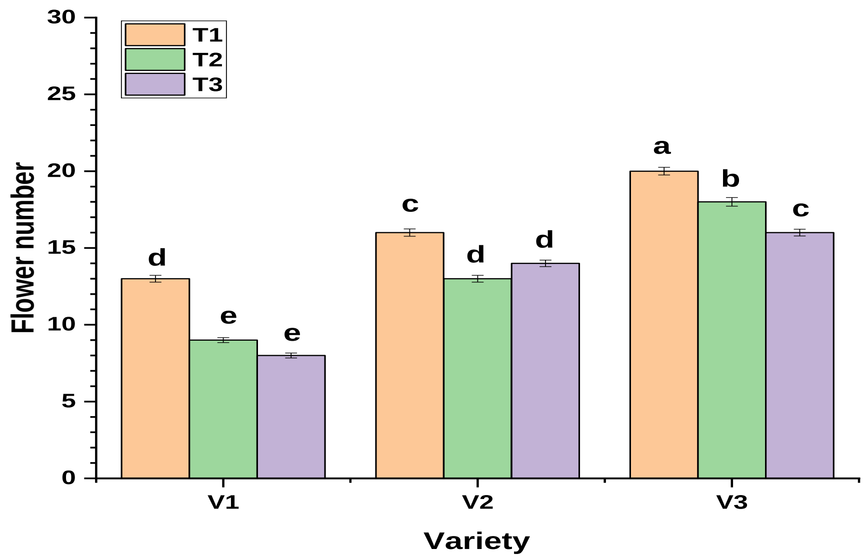

Figure 18. Effects of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on flower number at flowering stage with error bars

According to Sithole and Modi, 2015 eggplants that were subjected to drought stress produced fewer blooms than control. Anjum *et al*. (2011a) reported similar findings in maize, when subjected to water stress in tasseling stage. Drought-stressed soybean plants produced fewer flowers than plants that were properly irrigated (Dornbos *et al*., 1989). Waterlogging of soil often stops floral bud initiation and anthesis in some eggplant varieties, according to Ezin *et al*. (2010) and Kozlowski, 1997. Johnston, 1999 also reported similar findings in eggplant under waterlogged condition. Walter, 2004 and Ezin *et al*. (2010) also reported similar findings in tomato and *panicum sp*.

4.2.3 Parametric significance on fruit number

Table 12 shows data on ANOVA results of fruit number. From Table 12, variety (0.0001) followed by treatment (0.0001) impacted fruit number significantly since P values of them were lower than 0.05. Their interaction has p value (0.0195), lower than 0.05, which indicated its significance on fruit number. Variety (139) contributed more to fruit number rather than treatment (31) and their interaction (4) because of having more F value. A low CV value of 4.32% provided a precise analysis of the parameters for fruit number.

Table 12. ANOVA results of fruit number

Factors	DF	SS	MS	F	P
Rep	2	4.667	2.3333		
Variety	2	92.667	46.3333	139	0.0001
Treat	2	20.667	10.3333	31	0.0001
Variety*Treat	4	5.333	1.3333	4	0.0195
Error	16	5.333	0.3333		
Total	26	128.667			
CV			4.32%		

4.2.4 Influences of variety and treatment on fruit number

4.2.4.1 Effects of treatment conditions on fruit number

Figure 19 shows the effects of treatment on fruit number at fruiting stage. Overall, a high fruit number was observed for control (T1), whereas a low fruit number was noticed for waterlogging (T3) at any variety. At V1, a fruit number of 6 was found for T1, which decreased to 4 when T2 is applied. A further decrement of fruit number to 3 was observed for T3. At V2, a fruit number of 9 was recorded for T1, which reduced to 7 for T2. Afterward, an increase of fruit number (8) was seen for T3. At V3, the highest fruit number of 10 was noticed for T1 followed by T2 (9) while the lowest fruit number of 8 was found for T3.

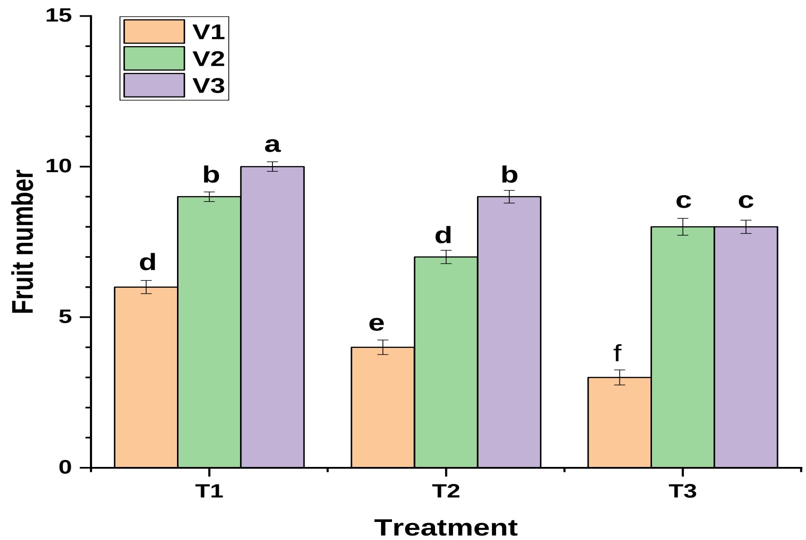

Figure 19. Effects of treatments (T1 = control, T2 = drought and T3 = waterlogging) on fruit number at the fruiting stage with error bars

4.2.4.2 Effects of variety on fruit number

Figure 20 shows the effects of variety on fruit number at fruiting stage. Overall, V3 (Purple king) showed the highest fruit number, whereas V1 (BARI Begun-5) revealed the lowest fruit number at different treatment conditions. At T1, a high fruit number of 10 was found for V3, which was followed by V2, whereas the lowest fruit number of 6 was obtained for V1. At T2, a high fruit number of 9 was found for V3, which decreased to 7 for V2. Further decline in fruit number to 4 was observed for V1. At T3, a fruit number of 8 was found for both V3 and V2, which reduced to 3 for V1.

It is concluded that application of the waterlogging stress in the variety affected the fruit number more compared to the drought stress. V3 (Purple king) was affected the least while V1 (BARI Begun-5) was affected the most by both waterlogging and drought conditions.

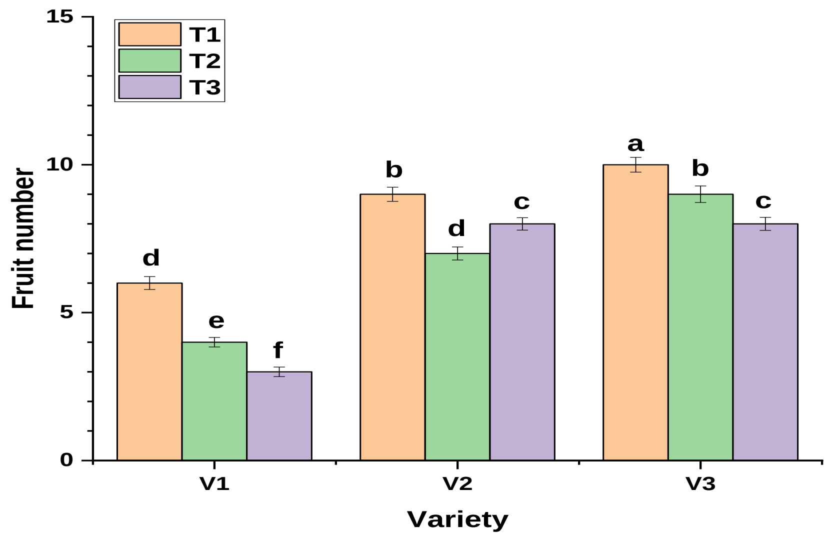

Figure 20. Effects of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on fruit number at the fruiting stage with error bars

According to Aujla *et al*. (2007) eggplants that were subjected to drought stress had produced poorer fruit set than normal irrigation. Zayova *et al. (*2017) found a similar finding in eggplant due to decreased photosynthetic activities. Drought-stressed soybean plants also produced fewer pods, fewer seeds per pod, and a smaller seed mass than plants that were properly irrigated (Dornbos *et al*., 1989). Waterlogging of soil reduced fruit set, and fruit enlargement in some eggplant species (Ezin *et al*., 2010). Chartzoulakis and Drosos, (1995) and Kirnak *et al*. (2001) also reported lower number of fruits in eggplant under waterlogged condition due to poorer nutrient translocation. Similar findings reported in tomato and pea by Loreti *et al*. (2012) under waterlogged condition.

4.2.5 Parametric significance on fruit length

Table 13 shows information on ANOVA results of fruit length.

Table 13. ANOVA results of fruit length

Factors	DF	SS	MS	F	P
Rep	2	4.912	2.456		
Variety	2	579.956	289.978	1467.6	0.0001
Treat	2	3.939	1.969	9.97	0.0015
Variety*Treat	4	2.397	0.599	3.03	0.0487
Error	16	3.161	0.198		
Total	26	594.365			
CV			3.54%		

From Table 13, variety (0.0001) followed by treatment (0.0015) impacted fruit length significantly since P values of them were lower than 0.05. Their interaction has p value (0.0487), lower than 0.05, which indicated its significance on fruit length. Variety (1467.6) contributed more to fruit length rather than treatment (9.97) and their interaction (3.03) because of having more F value. A low CV value of 3.54% provided a precise analysis of the parameters for fruit length.

4.2.6 Influences of variety and treatment on fruit length

4.2.6.1 Effects of drought and waterlogging condition on fruit length

Figure 21 shows the effects of treatment on fruit length at fruiting stage. Overall, almost similar trend was observed for both V2 and V3, but a slight change was noticed for V1 at any treatment. Moreover, V1 showed a lower fruit length than V3 followed by V2. At V1, a fruit length of 7.2 cm was obtained for T1, which decreased to 6 cm and 5.8 cm for T2 and T3, respectively. At V2, a fruit length of 17.2 cm was obtained for T1, which slightly drops to 16.4 cm for T2. The fruit length reached to 17 cm when T3 condition was applied. At V3. A fruit length of 15 cm was found for T1, T2 and T3.

4.2.6.2 Effects of variety on fruit length

Figure 22 shows the effects of variety on fruit length at fruiting stage. Overall, the control condition shows higher fruit length than drought and waterlogging conditions for all the varieties. V2 (BARI Begun-7) has a longer fruit than V3 (Purple king) followed by V1 (BARI Begun-7) at any treatment condition.

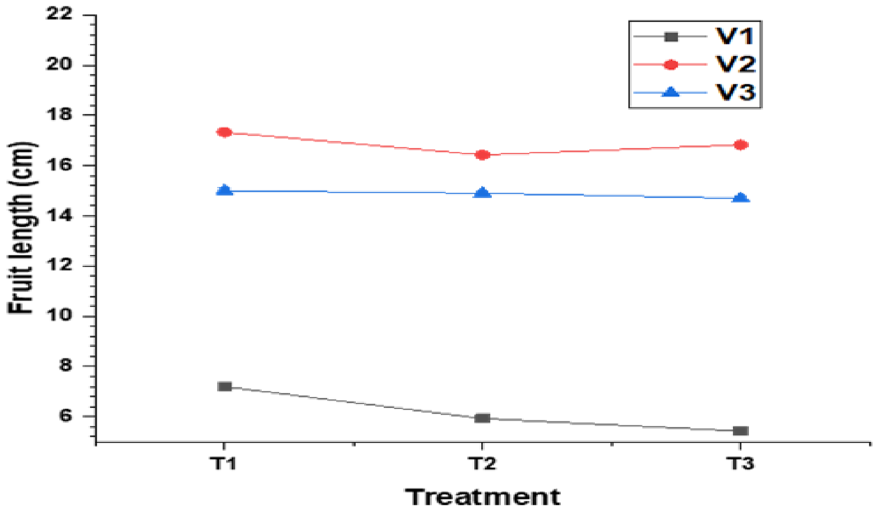

Figure 21. Effects of treatments (T1 = control, T2 = drought, and T3 = waterlogging) on fruit length at the fruiting stage with error bars

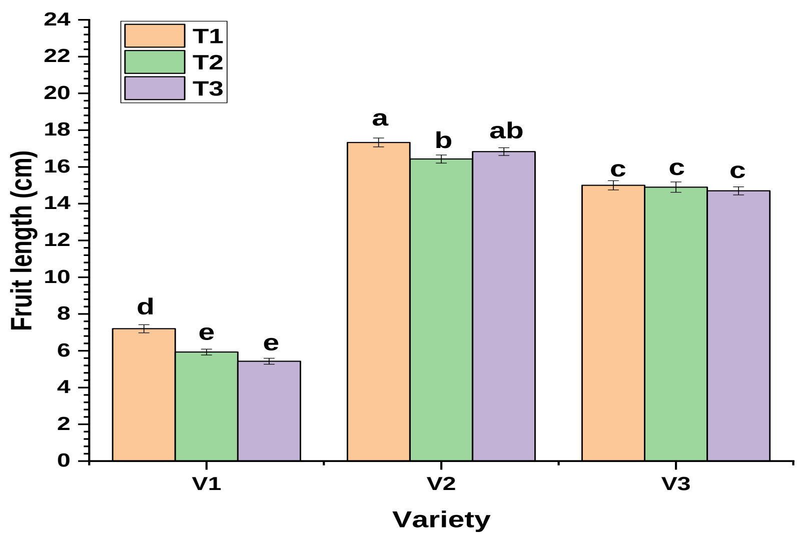

Figure 22. Effects of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on fruit length at the fruiting stage with error bars

At T1, a high fruit length of 17.33 cm was found for V2 while a low fruit length of 7.2 cm was measured for V1. At T2, a high fruit length of 16.43 cm was calculated for V2, which reduced to 14.9 cm and 5.93 cm for V3 and V1, respectively. At T3, a high fruit length of 16.83 cm was measured for V2, which reduced to 14.7 cm and 5.43 cm for V3 and V1, respectively. It is concluded that the fruit length of variety was not affected by the drought and waterlogging conditions. Furthermore, V2 had the longest fruits while V1 had the smallest fruits.

Inalpulat *et al.* (2014) reported reduced fruit size in eggplant due to lack of adequate photosynthesis and stomatal activities under drought stress condition. Similar findings reported by Chandra (2003). Rao *et al.* (2000) and Rahman *et al.* (1999) found smaller fruit in tomato under drought stress condition. Waterlogging of soil often reduced fruit enlargement in some eggplant species due to decreased metabolite translocation, according to Ezin *et al*. (2010) and Kozlowski (1997). Cannell *et al*. (1980) also reported similar findings in eggplant. In mung bean (Hossain, 2003) and okra (Altaf *et al*., 2015) found reduced pod size and shorter fruit under waterlogged condition.

4.2.7 Parametric significance on fruit diameter

Table 14 shows information on ANOVA results of fruit diameter. From Table 14, variety (0.0001) followed by treatment (0.0015) impacted fruit diameter significantly since P values of them were lower than 0.05. Their interaction has p value (0.001), lower than 0.05, which indicated its significance on fruit diameter. Variety (628.39) contributed more to fruit diameter rather than treatment (34.53) and their interaction (11.4) because of having more F value. A low CV value of 3.63% provided a precise analysis of the parameters for fruit diameter.

Table 14. ANOVA results of fruit diameter at fruiting stage.

Factors	DF	SS	MS	F	P
Rep	2	1.742	0.871		
Variety	2	456.98	228.49	628.39	0.0001
Treat	2	25.109	12.554	34.53	0.0015
Variety*Treat	4	16.578	4.144	11.4	0.001
Error	16	5.818	0.364		
Total	26	506.227			
CV			3.63%		

4.2.8 Influences of variety and treatment on fruit diameter

4.2.8.1 Effects of drought and waterlogging condition on fruit diameter

Figure 23 shows the effects of treatment on fruit diameter at fruiting stage.

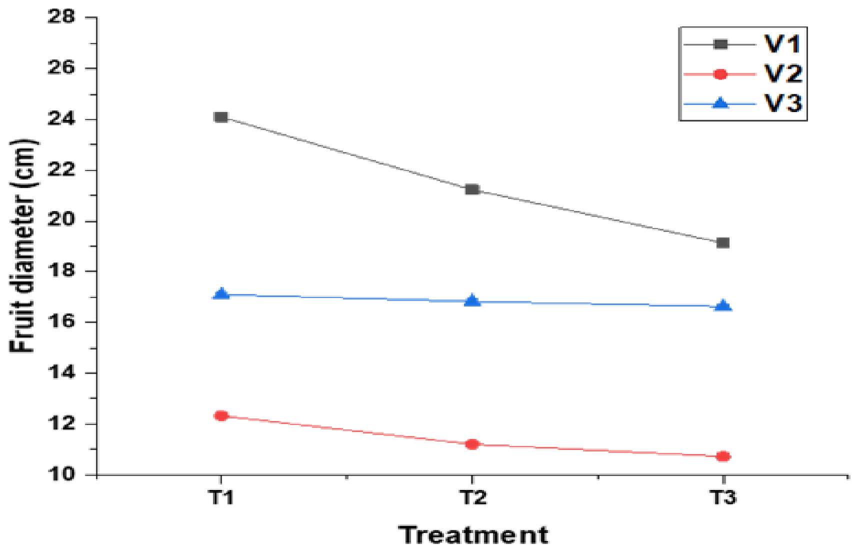

Figure 23. Effects of treatments (T1 = control, T2 = drought, and T3 = waterlogging) on fruit diameter at the fruiting stage with error bars

Overall, the fruit diameter of V1 (BARI Begun-5) has slightly been affected by both drought and waterlogging conditions, whereas the treatments did not show any impact on fruit diameter of both V3 and V2. From Figure 23, at V1, a high fruit diameter of 24 cm was measured at T1, which decreased to 21.5 cm and 19.6 cm at T2 and T3, respectively. At V2, a fruit diameter of 12.5 cm was estimated at T1 condition. Drought condition showed comparatively higher fruit diameter of 11.5 cm than the waterlogging condition. At V3, a fruit diameter of 17 cm was calculated at any treatment application.

4.2.8.2 Effects of variety on fruit diameter

Figure 24 shows the effects of variety on fruit diameter at fruiting stage. Overall, V3 followed by V2 was not affected by both drought and waterlogging conditions, but V1 showed the reverse trend. From Figure 24, at T1, the highest fruit diameter of 24.1 was measured for V1 while the lowest fruit diameter of 12.33 cm was calculated for V1. At

T2, a fruit diameter of 11.2 cm was obtained for V2, which increased to 16.83 cm and 21.33 cm for V3 and V1, respectively. At T3, a fruit diameter of 10.73 cm was obtained for V2, which increased to 16.63 cm and 19.13 cm for V3 and V1, respectively.

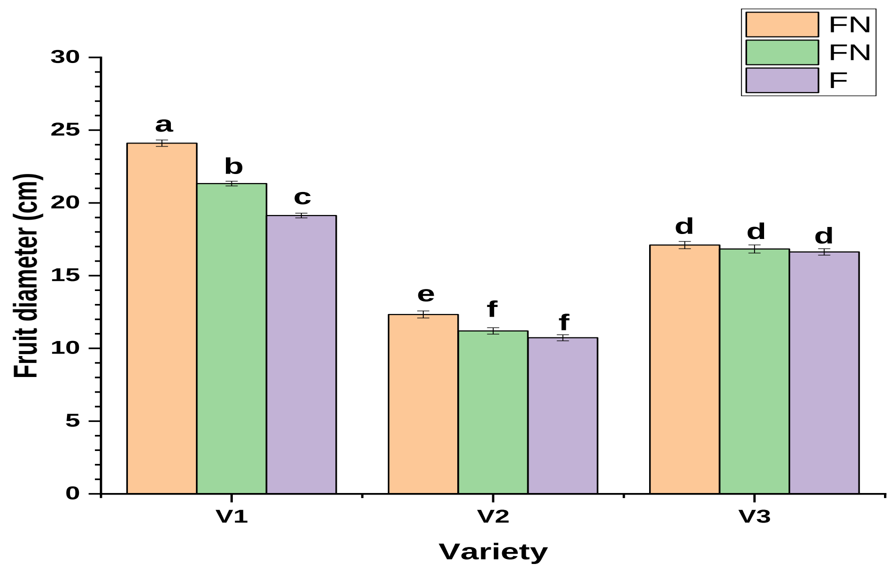

Figure 24. Effects of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on fruit diameter at the fruiting stage with error bars

It is concluded that waterlogging condition provides smaller fruit diameter than the drought condition for any variety. In addition to this, V3 showed almost same fruit diameter at drought and waterlogging conditions. However, both V1 and V2 were slightly affected by drought and waterlogging conditions.

Lovelli *et al*. (2007) reported decreased fruit size in eggplant under drought condition due to reduced vegetative growth and photosynthetic activities. Bsoul *et al*. (2016) also reported similar findings in eggplant. Similar findings reported by Pervez *et al*. (2009) in tomato and Okra (Kusvuran, 2012). Pervez *et al*. (2009), Okra (Kusvuran, 2012 and Kozlowski, 1997) found eggplant fruit with smaller diameter under waterlogged condition than control depending on severity and duration of stress period. Altaf *et al*. (2015) also reported reduced or more slender fruit under waterlogged condition than control in eggplant and okra.

4.2.9 Parametric significance on fruit weight

Table 15 shows information on ANOVA results of fruit weight. From Table 15, variety (0.0001) followed by treatment (0.0001) impacted fruit weight significantly since P values of them were lower than 0.05. Their interaction has p value (0.006), lower than 0.05, which indicated its significance on fruit weight. Variety (770.24) contributed more to fruit weight rather than treatment (146.74) and their interaction (8.87) because of having more F value. A low CV value of 1.24% provided a precise analysis of the parameters for fruit weight.

Table 15. ANOVA results of fruit weight at fruiting stage

Factors	DF	SS	MS	F	P
Rep	2	124.34	62.168		
Variety	2	1741.18	870.588	770.24	0.0001
Treat	2	331.71	165.854	146.74	0.0001
Variety*Treat	4	40.1	10.026	8.87	0.006
Error	16	18.08	1.13		
Total	26	2255.41			
CV			1.24%		

4.2.10 Influences of variety and treatment on fruit weight

4.2.10.1 Effects of drought and waterlogging condition on fruit weight

Figure 25 shows the effects of treatment on fruit weight at fruiting stage. Overall, both drought and waterlogging conditions affected fruit weight of the varieties in which the waterlogging condition influenced the fruit weight most. At V1, a fruit weight of 91.5 g was found for control condition (T1), which reduced gradually to 82 g and 80 g for T2 and T3, respectively. At V2, the lowest fruit weight of 73.5 g was calculated for waterlogging condition (T3), whereas the highest fruit weight of 80 g was obtained for T1. At V3, a fruit weight of 99 g was found for control condition (T1), which reduced steadily to 95.5 g and 93.5 g for T2 and T3, respectively.

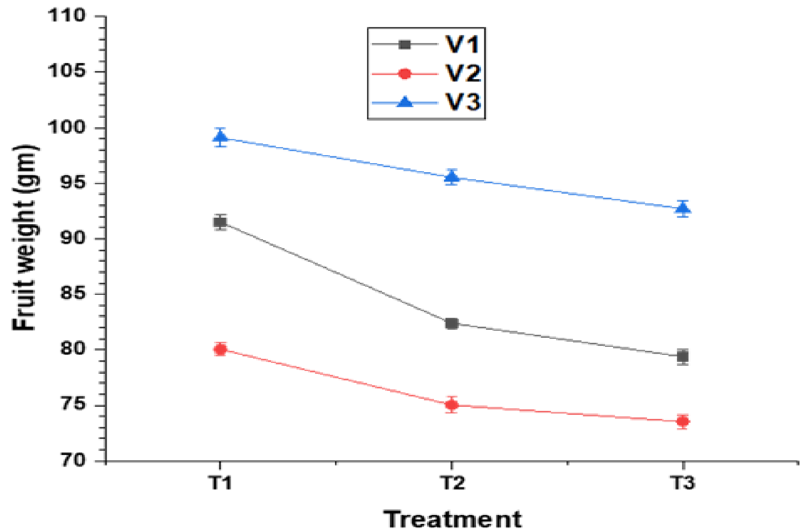

Figure 25. Effects of treatments (T1 = control, T2 = drought, and T3 = waterlogging) on fruit weight at the fruiting stage with error bars

4.2.10.2 Effects of variety on fruit weight

Figure 26 shows the effects of variety on fruit weight at fruiting stage. Overall, V3 (purple king) provided a high fruit weight and V2 (BARI Begun-7) yielded a low fruit weight at different treatment conditions. At control (T1), a fruit weight of 99 g was obtained for V3, which witnessed a sharp decline in fruit weight to 80 g for V2. Afterward, it increased to 91.5 g for V1. At drought (T2), the highest fruit weight of 95 g was measured for V3, whereas the smallest fruit weight of 75 g was estimated for V2. At waterlogging (T3), a fruit weight of 92 g was obtained for V3, which witnessed a sharp decline in fruit weight to 73.5 g for V2. Afterward, it increased to 79 g for V1.

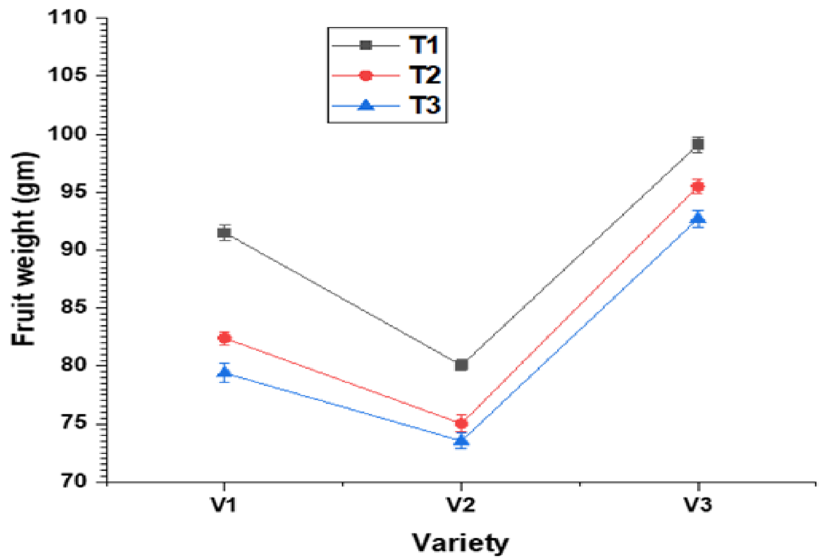

Figure 26. Effects of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on fruit weight at the fruiting stage with error bars

It is concluded that the waterlogging condition affected the varieties more than the drought condition. Therefore, the waterlogging condition provided the lowest fruit weight of the varieties.

Abd El-Al *et al*. (2008) reported reduced fruit weight of eggplant under drought stress codition due to decreased physiological and metabolic activities. Ilahi *et al*. (2018) also found similar findings. Drought stress caused a significant loss in 100 kernels weight when maize plants were exposed to drought stress at the tasseling stage (Anjum *et al*., 2011a). under waterlogged condition lower fruit weight found in eggplant according to Senyigit *et al*. (2011) and Ezin *et al*. (2010). Similar findings found in tomato and wheat according to Loreti *et al*. (2016).

4.2.11 Parametric significance on fruit yield

Table 16 shows information on ANOVA results of fruit yield. From Table 16, variety (0.0001) followed by treatment (0.0015) influenced fruit yield significantly since P values of them were lower than 0.05. Their interaction has p value (0.0416), lower than 0.05, which indicated its significance on fruit yield. Variety (247.66) contributed more to fruit yield rather than treatment (70.18) and their interaction (3.19) because of having more F value. A low CV value of 4.63% provided a precise analysis of the parameters for fruit yield.

Table 16. ANOVA results of fruit yield

Factors	DF	SS	MS	F	P
Rep	2	0.01362	0.00681		
Variety	2	1.79892	0.89946	247.66	0.0001
Treat	2	0.50979	0.25489	70.18	0.0015
Variety*Treat	4	0.0464	0.0116	3.19	0.0416
Error	16	0.05811	0.00363		
Total	26	2.42683			
CV			4.63%		

4.2.12 Influences of variety and treatment on fruit yield

4.2.12.1 Effects of drought and waterlogging condition on fruit yield

Figure 27 shows the effects of treatment on fruit yield at fruiting stage. Overall, both drought and waterlogging conditions affect fruit yield per pot. Among the treatments, the waterlogging impacted on the fruit yield most. For V1, a fruit yield of 1 kg per pot was obtained when control has been applied, which decreased to 0.7 kg per pot and 0.6 kg per pot for T2 and T3, respectively. For V2, control (T1) yielded the fruit yield of 1.14 kg per pot, which gradually decreased to 0.94 kg per pot for drought (T2) followed by the waterlogging (0.76 kg per pot). For V3, a fruit yield of 1.48 kg per pot was obtained while applying control (T1), which decreased to 1.38 kg per pot and 1.32 kg per pot for drought (T2) and waterlogging (T3), respectively.

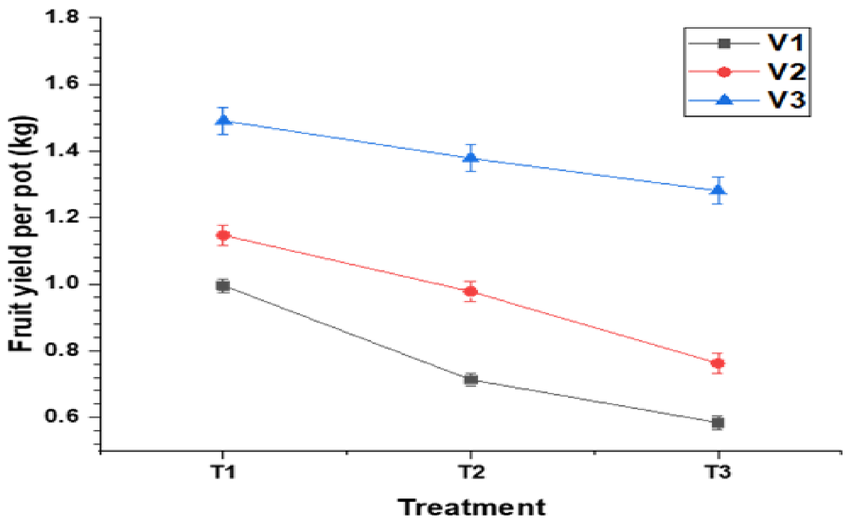

Figure 27. Effects of treatments (T1 = control, T2 = drought, and T3 = waterlogging) on fruit yield at the fruiting stage with error bars

4.2.12.2 Effects of variety on fruit yield

Figure 28 shows the effects of variety on fruit yield at fruiting stage. Overall, a high rate of production was recorded for V3 (Purple king) while V1 (BARI Begun-5) provided a low fruit yield at different treatment conditions. At T1, the highest fruit yield of 1.491 kg per pot was accounted for V3, whereas the lowest fruit yield of 0.996 kg per pot was recorded for V1. At T2, a high fruit yield of 1.378 kg per pot was counted for V3, which reduced to 0.978 kg per pot and 0.713 kg per pot for V2 and V1, respectively. At T3, the highest fruit yield of 1.281 kg per pot was accounted for V3, whereas the lowest fruit yield of 0.584 kg per pot was recorded for V1.

It is concluded that purple king variety (V3) enables to provide a high fruit yield while BARI Begun 5 (V1) has a low fruit yield with both drought and waterlogging conditions. With the waterlogging condition, the varieties provided the lowest fruit yield. Therefore, the varieties were affected by the waterlogging most.

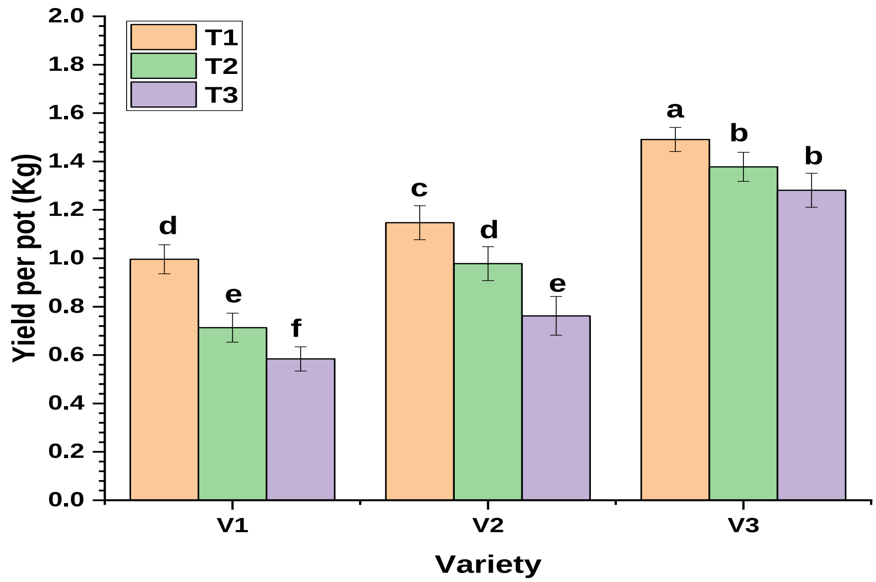

Figure 28. Effects of variety (V1 = BARI begun-5, V2 = BARI begun-7 and V3 = Purple king) on fruit yield at the fruiting stage with error bars

Reduced yield and poor color development in the fruit are the effects of a lack of water on eggplant (Kemble and Sanders, 2000). Drought hampered mitosis, resulting in lower growth and yield attributes due to cell elongation and expansion (Hussain *et al*., 2008). Drought stress caused a significant loss in yield/plant, biological yield/plant, and harvest index when maize plants were exposed to drought stress at the tasseling stage (Anjum *et al*., 2011a). According to Bafeel and Moftah, 2008, the negative impact of drought stress on eggplant yield and components may be due to a reduction in vegetative growth. Waterlogging affects about 10-15 million hectares of wheat worldwide, resulting in output losses of 20 to 50 percent per year (Hossain and Uddin, 2011). Yield reduction in eggplant under waterlogged condition reported by Senyigit *et al*. (2011) and Solaiman *et al*. (2007). Similar findings reported in other grain crops, such as barley, canola, lupins, field peas (Bakker *et al*., 2007; Romina *et al*., 2018).

4. 3 Anatomical Change in eggplant leaf under drought and waterlogged condition (Microscopic view):

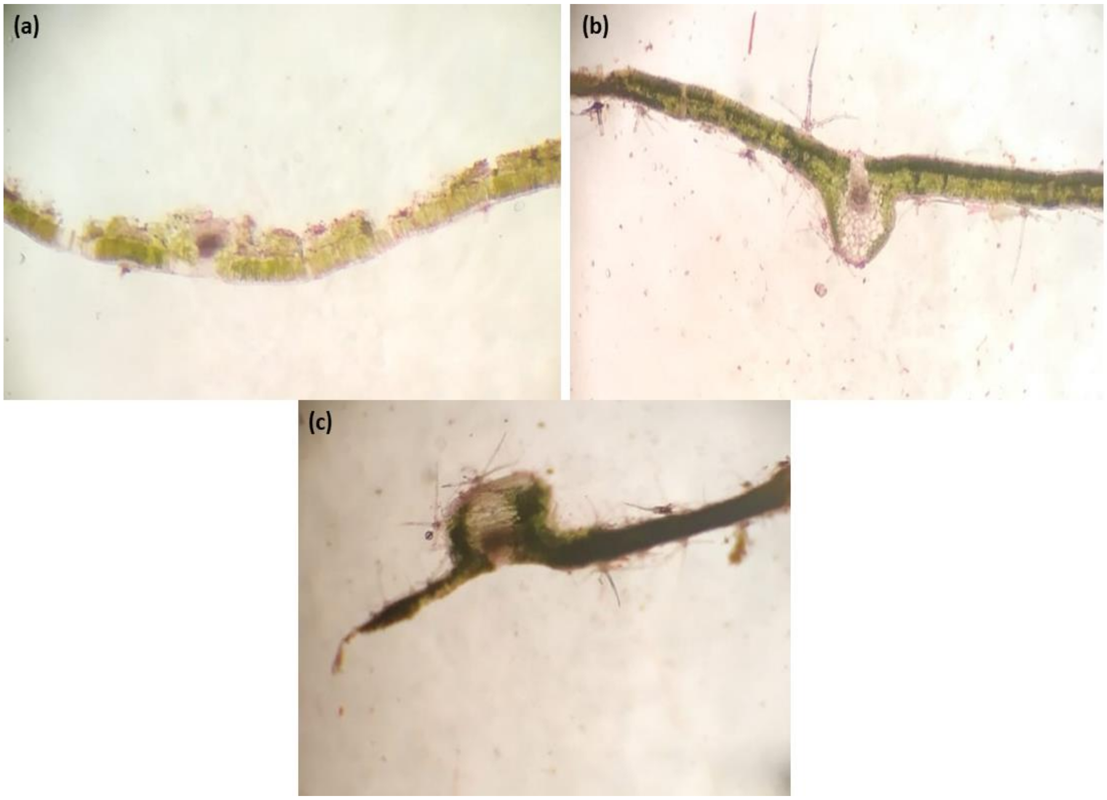

Figure 29. Microscopic view of BARI Begun-5 leaf representing anatomical change under drought and waterlogged condition; a) Drought b) Control c) Waterlogged

Among three eggplant variety BARI Begun-5 (V1), BARI Begun-7 (V2) and Purple king (V3), the most affected variety was BARI Begun-5 under drought (T2) and waterlogged (T3) condition where T3 was more prominent. Where leaf anatomy with stomatal structure is more damaged in waterlogging and drought condition compared to control, which lowered the photosynthetic activity and ultimately causes reduced growth and yield of eggplant.

Folzer *et al*. (2006) and Inalpulat *et al.* (2014) reported that waterlogged stressed eggplants have increased stomata resistance and restricted water intake due to modified leaf anatomy, resulting in an internal water deficit and oxygen deficiency. Yordanova *et al*. (2004) also reported similar findings in tomato where, Oxygen shortage causes a significant decrease in net photosynthetic rate due stomatal change. Stomata closure is responsible for the decrease in transpiration and photosynthesis (Liao and Lin, 1994). Hsiao *et al*. (2005) reported that prolonged and severe drought stress stunted growth by lowering photosynthetic rate through stomata closure resulted from modified leaf anatomy and metabolic impacts on photosynthesis. Samarah *et al*. (2009) and Del Blanco *et al*. (2000) also reported similar findings in tomato and okra.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATION

This section outlines the summary of thesis, conclusions drawn from the research findings, and recommendation for further endeavors.

SUMMARY

Eggplant is widely consumed vegetable in the world. The production of it may be significantly affected by the major abiotic stresses like drought and waterlogging resulted from the climate change. The experiment was conducted from October 2019 to March 2020 at agroforestry field in Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. In this research work, the impacts of both drought and waterlogging conditions on the vegetative growth of eggplant and physiological response have been evaluated. This study also targets to assess the variations of eggplant fruit yield under the different drought and waterlogging conditions. It was two factorials pot experiment which was laid out in a Randomized Complete Block Design (RCBD) with three replications. The factors are; Factor A: Eggplant varieties (Three varieties such as BARI Begun-5, BARI Begun-7 and Purple King) and Factor B: Control(T_1), Drought(T_2) and Waterlogging(T_3). The total treatment combinations were 9(3x3). At the beginning, the seedlings were prepared and thirty days old seedlings were transplanted to the prepared plastic pots as per RCBD. The treatments such as drought and waterlogging were applied on the plants when they were at the flowering stage after 45 days of transplanting. A water basin was adopted to apply the waterlogging stresses, which were imposed for eight days and drought stress was also imposed for eight days by withholding water. After the treatment recovery, the data on growth parameters, physiological parameter and yield contributing character of eggplant were taken to analyze. The statistical (STATISTIX 10 Software) and graphical analyses were done to address the set objectives. The significance of the difference among the means was evaluated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984). The results showed that both the drought and waterlogging provided significant stresses on the plant growth and fruit production. Among them, the waterlogging stress affected the eggplants more. Furthermore, Purple King showed its capability to provide a high fruit production under the stresses.

At 65 and 80 DAT highest plant height (36.52 cm and 40.53 cm) was obtained from purple king(V_3) under control(T_1) condition. The lowest plant height (23.1cm and 23.4cm) was obtained from BARI Begun-5(V_1) under waterlogging(T_3) condition. At 65 and 80 DAT highest branch number (7 and 8) was obtained from purple king(V_3) under control(T_1) condition. Whereas the lowest number of branch (3 and 4) was obtained from BARI Begun-5(V_1) under waterlogging (T_3) condition. At 65 and 80 DAT highest leaf number of 35 and 43 was obtained from purple king(V_3) under control(T_1) condition. Whereas the lowest leaf number of 24 and 27 was obtained from BARI Begun-5(V1) under waterlogging condition.

At 67 and 80 DAT highest chlorophyll content of 57.4 and 64.3 SPAD unit was measured from purple king(V_3) under control (T_1) condition. Whereas the lowest chlorophyll content of 45.6 and 47.53 SPAD unit was measured for BARI Begun-5(V_1) under waterlogging (T_3) condition. At flowering stage V_3 (Purple king) shows the highest flower number of 20 under control(T_1) condition, whereas V_1 (BARI Begun-5) reveals the lowest flower number of 8 under waterlogging(T_3) condition. At fruiting stage V_3 (Purple king) shows the highest fruit number of 10 under control(T_1) condition, whereas V_1 (BARI Begun-5) reveals the lowest fruit number of 3 under waterlogging(T_3) condition. V_2 (BARI Begun-7) has a longer fruit than V_3 (Purple king) followed by V_1 (BARI Begun-5) at any treatment condition. Purple king (V_3) showed almost same fruit diameter at drought(T_2) and waterlogging(T_3) conditions. Where both V1 and V2 were slightly affected by drought and waterlogging conditions. The highest fruit weight of 99gm was measured under control(T_1) condition for V_3 (Purple king), whereas V2 (BARI Begun-7) reveals the lowest fruit weight of 73.5gm under waterlogging(T_3) condition. The highest fruit yield of 1.48 kg per pot was measured under control(T_1) condition for V_3 (Purple king), whereas V1 (BARI Begun-5) reveals the lowest fruit yield of 0.6 kg per pot under waterlogging(T_3) condition.

CONCLUSION

In this experiment impact of major abiotic stresses both drought and waterlogging on the vegetative growth, physiological response and yield characteristics of eggplant have been evaluated. Considering the findings of the present experiment following conclusions can be extracted.

1. Drought and waterlogging had the greatest impact on BARI Begun 5, where had the least impact on Purple King. The highest plant height, branch number, leaf number and SPAD value of 40.53 cm, 8, 43, 64.3, respectively obtained at control condition in Purple King variety, where plant height of 38.2 cm and 37.7 cm, branch number of 7 and 5, leaf number of 41 and 37, SPAD value of 62.3 and 61.2, respectively obtained at drought and waterlogging condition. The waterlogging condition affected the responses more compared to the drought condition.
2. The highest flower number, fruit number, fruit weight and fruit yield of 20, 10, 99 g, 1.49 kg per pot, respectively obtained at control condition in case of Purple King, where flower number of 19 and 17, fruit number of 9 and 8, fruit weight of 95.5g and 93.5g, fruit yield of 1.38 kg and 1.32 kg, respectively obtained at drought and waterlogging condition. When compared to drought, the waterlogging condition had a greater impact on the outputs related to the eggplant fruit yield.

Therefore, due to more enduring capability purple king variety can be added in the existing cropping pattern at both drought and waterlogged prone area in tropical and subtropical region.

RECOMMENDATION

Following recommendations and suggestions should be followed for undertaking further research regarding this topic:

- Further experiment may be carried out with other eggplant variety at different duration of drought and waterlogging in different growth stage of eggplant life cycle.
- Molecular & biochemical mechanism of drought & waterlogging tolerance may take in consideration in further research.
- Similar research work should be conducted with wide range of crops and also with different duration of treatment in kharif season.

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APPENDICES

APPENDIX I: List of necessary tables for results and discussion

Table 1. Effect of treatment on plant height

Treatment	Plant height at 65 days	Plant height at 80 days
T1	32.167a	36.5a
T2	30.167b	32.6b
T3	28.644c	30.278c
SE (±)	0.3892	0.4995
LSD	0.8251	1.0588

Table 2. Effect of variety on plant height

Variety	Plant height at 65 days	Plant height at 80 days
V1	35.511a	38.578a
V2	29.8b	33.111b
V3	25.667c	27.689c
SE (±)	0.3892	27.689
LSD	0.8251	1.0588

Table 3. Effect of interactions between treatment and variety on plant height

Variety*Treatment	Plant height at 65 days	Plant height at 80 days
V3*T1	36.5a	40.567a
V3*T2	35.433ab	38.1b
V3*T3	34.6b	37.067b
V2*T1	31.6c	36.567b
V2*T2	29.6d	32.433c
V1*T1	28.4d	32.367c
V2*T3	28.2d	30.333d
V1*T2	25.467e	27.267e
V1*T3	23.133f	23.433f
SE (±)	0.6742	0.8651
LSD	1.4292	1.8339

Table 4. Effect of treatment on branch number(BN)

Treatment	BN at 65 days	BN at 80 days
T1	5.2222a	6.6667a
T2	4.4444b	5.3333b
T3	3.5556c	4.5556c
SE (±)	0.1898	0.3223
LSD	0.4023	0.6834

Table 5. Effect of variety on branch number(BN)

Variety	BN at 65 days	BN at 80 days
V3	5.5556a	6.7778a
V2	4.4444b	5.8889b
V1	3.2222c	3.8889c
SE (±)	0.1898	0.3223
LSD	0.4023	0.6834

Table 6. Effect of interactions between treatment and variety on branch number (BN)

Variety*Treatment	BN at 65 days	BN at 80 days
V3*T1	6.6667a	8.3333a
V3*T2	5.6667b	7b
V2*T1	5bc	7b
V2*T2	4.6667cd	5.6667c
V3*T3	4.3333cde	5c
V1*T1	4de	4.6667cd
V2*T3	3.6667ef	5c
V1*T2	3fg	3.3333e
V1*T3	2.6667g	3.6667de
SE (±)	0.3287	0.5583
LSD	0.6968	1.1836

Table 7. Effect of treatment on leaf number (LN)

Treatment	LN at 65 days	LN at 80 days
T1	31.556a	38a
T2	29.556b	35.111b
T3	27.889c	32.444c
SE (±)	0.1361	0.2268
LSD	0.2885	0.4808

Table 8. Effect of variety on leaf number (LN)

Variety	LN at 65 days	LN at 80 days
V3	33.889a	41.222a
V2	28.667b	33.889b
V1	26.444c	30.444c
SE (±)	0.1361	0.2268
LSD	0.2885	0.4808

Table 9. Effect of interactions between treatment and variety on leaf number (LN)

Variety*Treatment	LN at 65 days	LN at 80 days
V3*T1	35.333a	43.667a
V3*T2	34b	41.333b
V3*T3	32.333c	38.667c
V2*T1	30.333d	36.333d
V1*T1	29e	34e
V2*T2	28.333f	33.667e
V2*T3	27.333g	31.667f
V1*T2	26.333h	30.333g
V1*T3	24i	27h
SE (±)	0.2357	0.3928
LSD	0.4997	0.8328

Table 10. Effect of treatment on SPAD Value or Chlorophyll content(CC)

Treatment	CC at 67 days	CC at 80 days
T1	54.811a	59.911a
T2	52.278b	57.044b
T3	50.467c	54.322c
SE (±)	0.3918	0.3253
LSD	0.8305	0.6895

Table 11. Effect of variety on SPAD Value or Chlorophyll content(CC)

Variety	CC at 67 days	CC at 80 days
V3	55.867a	62.6a
V2	53.078b	57.067b
V1	48.611c	51.611c
SE (±)	0.3918	0.3253
LSD	0.8305	0.6895

Table 12. Effect of interactions between treatment and variety on SPAD Value or Chlorophyll content (CC)

Variety*Treatment	CC at 67 days	CC at 80 days
V3*T1	57.433a	64.3a
V3*T2	55.533b	62.3b
V2*T1	55.3b	61.2b
V3*T3	54.633b	59.733c
V2*T2	52.733c	57.233d
V1*T1	51.7cd	55.7e
V2*T3	51.2d	54.233f
V1*T2	48.567e	51.6g
V1*T3	45.567f	47.533h
SE (±)	0.6786	0.5634
LSD	1.4385	1.1943

Table 13. Effect of treatment and variety on flower number

Treatment	Flower number	Variety	Flower number
T1	16.222a	V3	17.889a
T2	13.222b	V2	14b
T3	12.778b	V1	10.333c
SE (±)	0.3629	SE (±)	0.3629
LSD	0.7693	LSD	0.7693

Table 14. Effect of interactions between treatment and variety on flower number

Variety*Treatment	Flower number
V3*T1	19.667a
V3*T2	17.667b
V3*T3	16.333c
V2*T1	15.667c
V2*T3	13.667d
V1*T1	13.333d
V2*T2	12.667d
V1*T2	9.333e
V1*T3	8.333e
SE (±)	0.6285
LSD	1.3324

Table 15. Effect of treatment and variety on fruit number

Variety	Fruit number	Treatment	Fruit number
V3	8.6667a	T1	8.1111a
V2	7.6667b	T2	6.4444b
V1	4.3333c	T3	6.1111b
SE (±)	0.2722	SE (±)	0.2722
LSD	0.577	LSD	0.577

Table 16. Effect of interactions between treatment and variety on fruit number

Variety*Treatment	Fruit number
V3*T1	9.6667a
V2*T1	8.6667b
V3*T2	8.6667b
V2*T3	7.6667c
V3*T3	7.6667c
V2*T2	6.6667d
V1*T1	6d
V1*T2	4e
V1*T3	3f
SE (±)	0.4714
LSD	0.9993

Table 17. Effect of treatment and variety on fruit weight

Variety	Fruit weight	Treatment	Fruit weight
V3	95.8a	T1	90.244a
V2	84.456b	T2	84.322b
V1	76.211c	T3	81.9c
SE (±)	0.5012	SE (±)	0.5012
LSD	1.0624	LSD	1.0624

Table 18. Effect of interactions between treatment and variety on fruit weight

Variety*Treatment	Fruit weight
V3*T1	99.1a
V3*T2	95.533b
V3*T3	92.767c
V1*T1	91.567c
V1*T2	82.4d
V2*T1	80.067e
V1*T3	79.4e
V2*T2	75.033f
V2*T3	73.533f
SE (±)	0.8681
LSD	1.8402

Table 19. Effect of treatment and variety on fruit length

Variety	Fruit length	Treatment	Fruit length
V2	16.867a	T1	13.178a
V3	14.867b	T2	12.422b
V1	6.189c	T3	12.322b
SE (±)	0.2095	SE (±)	0.2095
LSD	0.4442	LSD	0.4442

Table 20. Effect of interactions between treatment and variety on fruit length

Variety*Treatment	Fruit length
V2*T1	17.333a
V2*T3	16.833ab
V2*T2	16.433b
V3*T1	15c
V3*T2	14.9c
V3*T3	14.7c
V1*T1	7.2d
V1*T2	5.933e
V3*T3	5.433e
SE (±)	0.3629
LSD	0.7694

Table 21. Effect of treatment and variety on fruit diameter

Variety	Fruit diameter	Treatment	Fruit diameter
V1	21.489a	T1	17.844a
V3	16.856b	T2	16.422b
V2	11.422c	T3	15.5c
SE (±)	0.2843	SE (±)	0.2843
LSD	0.6026	LSD	0.6026

Table 22. Effect of interactions between treatment and variety on fruit diameter

Variety*Treatment	Fruit diameter
V1*T1	24.1a
V1*T2	21.233b
V1*T3	19.133c
V3*T1	17.1d
V3*T2	16.833d
V3*T3	16.633d
V2*T1	12.333e
V2*T2	11.2f
V2*T3	10.733e
SE (±)	0.4923
LSD	1.0437

Table 23. Effect of treatment and variety on yield per pot

Variety	Yield per pot	Treatment	Yield per pot
V3	1.3834a	T1	1.2114a
V2	0.9628b	T2	1.0234b
V1	0.7643c	T3	0.8757c
SE (±)	0.0284	SE (±)	0.0284
LSD	0.0602	LSD	0.0602

Table 24. Effect of interactions between treatment and variety on fruit diameter

Variety*Treatment	Yield per pot
V3*T1	1.491a
V3*T2	1.3787b
V3*T3	1.2807b
V2*T1	1.1477c
V1*T1	0.9957d
V2*T2	0.9783d
V2*T3	0.7623e
V1*T2	0.7133e
V1*T3	0.584f
SE (±)	0.0492
LSD	0.1043

Table 25. Mechanical and chemical features of the experimental soil (Source: SRDI, Khamabari, Dhaka)

Mechanical features		Chemical features	
Particle size	Composition	Soil characters	Value
Texture	Loamy	Organic matter	1.44%
Sand	40%	K	0.15 meq/100 g soil
Silt	40%	Ca	1 meq/100 g soil
Clay	20%	Mg	1 meq/100 g soil
		N	0.072
		P	22.08 µg/ 100 g soil
		S	25.98 µg/ 100 g soil
		B	0.48 µg/ 100 g soil
		Cu	3.54 µg/ 100 g soil
		Fe	262.6 µg/ 100 g soil
		Mn	164 µg/ 100 g soil
		Zn	3.32 µg/ 100 g soil

APPENDIX II: Some photographs of the experiment

Plate 5. The completed transplantation based on RCBD.

Plate 6. Tagging the pots

Plate 7. Watering the eggplants

Plate 8. Eggplants at flowering stage

Plate 9. Application of waterlogging condition

Plate 10. Application of drought condition

Plate 11. Field visit of respected supervisor

Plate 12. Yield of Purple King

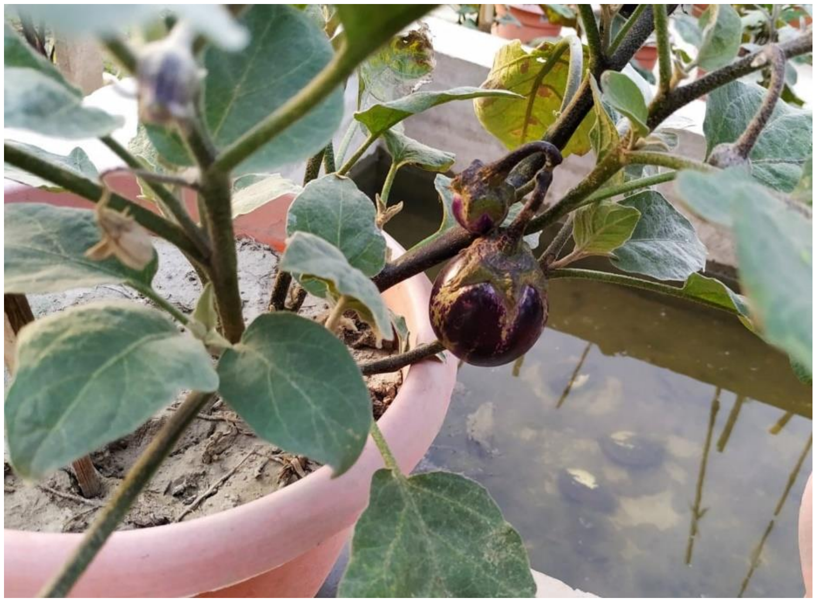

Plate 13. Yield of BARI Begun-5

Plate 14. Yield of BARI Begun-7