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Waterlogging Effect on Growth, Yield and Physiological Responses of Blackgram (*Vigna Mungo* L.) Genotypes

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Abstract: Waterlogging is one of the major abiotic stresses that affect growth, yield and physiological traits of blackgram. To evaluate the performance of six different blackgram genotypes imposed under waterlogging stress, a pot experiment was conducted in a two factor randomized complete block design with three replications in the Agroforestry and Environmental Science field lab at Sher-e-Bangla Agricultural University. Plastic pots with 30 days old plants were placed into a brick water chamber with waterlogging depth of 3-5 cm top of soils for 7 days to simulate waterlogging. Significant reduction was observed for plant height, number of leaves, SPAD value, nodule number, pod length, seeds per pod, yield per plant and the degree of reduction varied prominently over the blackgram genotypes. The number of leaves and SPAD value were higher in BARI Mash-3 which was 5.0 and 46.03 SPAD units in waterlogging situation. Among the six genotypes, BARI Mash-1 performed the best in respect of grain yield (5.04 g/plant) production followed by BARI Mash-3 (4.58 g/plant) under waterlogging condition. Stress tolerance index (STI) and yield index (YI) were highest in BARI Mash-2 (1.87) and BARI Mash-1 (1.67). Hence, these varieties can be added in the existing cropping pattern as a short-term waterlogging tolerant plant. In the future, waterlogging stress tolerant varieties with more suitable genetic base of blackgram plants needed to identify and utilize the novel traits of donors are now required in breeding programs.

Keywords: *Vigna mungo* L.; Waterlogging; Nodule; Stress tolerance index; Yield.

INTRODUCTION

Bangladesh is the largest delta in the world. It is a country widely known to be amongst the foremost climate-vulnerable nations, globally (Sarker *et al*., 2020). Weather and climatic factors also important as improved crop varieties and irrigation systems, which play a significant role to agricultural crop productivity. It is assumed that climate change aggravates similar hazardous incidents, including floods, riverbank erosion, drought, cyclone, waterlogging, etc., which adversely influences crop production, socioeconomic improvement and living communities. Waterlogging is simply the saturation of soil with water, either temporarily or permanently. Waterlogging constraints plant growth and leading to the death of certain crops and plants. The primary cause of waterlogging in crop plants is oxygen deprivation. A total of 532,000 hectares of crops were lost in Bangladesh while the remaining land suffered varying degrees of damage (BBS, 2019). Soil flooding is a widespread phenomenon that has a significant impact on approximately 10% of the Earth's land surface, as reported by the Food and Agriculture Organization (FAO, 2002). Pulse crops are classified as grain legumes, which serve as a crucial dietary source of protein, calories, minerals and some vitamins. Pulses sometimes referred to as the "peasant's meat," are regarded as the most cost-effective forms of protein. Additionally, these crops exhibit tolerance to a diverse range of agro-ecological and managerial variables. Bangladesh cultivates a significant quantity of pulse crops in terms of both land area and yield (BBS, 2016).

Blackgram (*Vigna mungo* L.), is a grain legume exhibits self-pollination grown extensively in the tropics and subtropics (Nagarjuna *et al*., 2001). As a short-lived crop, it clears the field quickly, making room for winter crops like mustard and lentils cultivated in restricted and rain-fed conditions. According to the Ministry of Agriculture (MoA, 2019), it ranks fourth in terms of both land area and production. Blackgram contain a significant quantity of protein (24-26%), 56% carbohydrate, 2 % fat, 4 % minerals and 0.4 % vitamins. Bangladesh consumes 14.30 g of pulses per day, compared to 45 g recommended (BBS, 2013). Most health organizations recommend eating pulses frequently to minimize the risk of coronary heart disease, diabetes, obesity and excessive cholesterol (Geil and Anderson, 1994). Blackgram is often cultivated in Bangladesh in late winter and summer using rain-fed conditions. In the northern or northwestern region of Bangladesh, a variety of plant commonly referred to as 'Mashkalai'. Compared to other legumes, blackgram has more methionine (Tsou and Hsu, 1978). Blackgram seeds are eaten in pulse soup. Blackgram accounts for 9.5% of pulse production (0.0631 million ton) in Bangladesh on 0.0687 million hectares (DAE, 2016). The average blackgram yield is 1.01 t/ha (BBS, 2019), substantially lower than in blackgram-growing countries. Blackgram can be grown as an agroforestry crop since it produces grain, nitrogen, and animal feed.

In order to enhance pulse production, it is imperative to expeditiously expand the cultivation of pulse crops over all feasible regions in Bangladesh. Nonetheless, waterlogging is a persuasive challenge during pulse production in flood-prone areas in Bangladesh. Waterlogging reduces plant-environment gas exchange (Maberly and Spense, 1989). Oxygen shortage is the biggest challenge for flooded plants (Crawford and Brandle, 1996). Flooding-induced stress may directly affect guard cells, closing stomata and reducing photosynthesis (Bradford and Hsiao, 1982). There is a requirement to generate blackgram varieties that are both stress tolerant and high producing. This can be achieved by integrating the sporadically distributed tolerance traits seen in many related genotypes. Hence, to cultivate blackgram in flooding condition, it is needed to develop waterlogging tolerant high yielding varieties through the evaluation of several genotypes and mutations. However, the physiological and yield response of waterlogging in blackgram has not been studied as intensively done in some other legumes like soybean and (Khadeja *et al*., 2022 and Olorunwa *et al*., 2022). Therefore, to identify the waterlogging stress tolerant genotypes, research was conducted to assess the changes in the morphological, physiological and yield parameters of blackgram genotypes under waterlogging condition.

MATERIALS AND METHODS

Experimental area

A pot experiment was conducted from September to December 2022 at the Agroforestry Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh with six blackgram genotypes collected from Pulse Research Center, BARI, Gazipur. This location is 90.2°E, 23.5°N and 8.25 m (Provide a study area map for better understanding of the readers) above sea level. The experimental area had a subtropical monsoon climate with substantial rainfall in kharif (April-September) and little in Rabi (October-March).

Pot preparation and plant management

The seeds of blackgram were planted in the earthen pots which filled with a mixture of clay-loam soil and farm yard manure in a ratio of 4:1. The planting was carried out during the summer-rainy season. A total of 12 kg of soil were allocated into each pot and subsequently treated with cow dung mixture, compost (¼ of the soil volume), urea (0.2g), triple super phosphate (0.4g), and murate of potash (0.12g). At the outset, a total of four seeds were sown at a depth of 1cm in each individual pot, which was subsequently reduced to three plants per pot after a span of 20 days. Intercultural operations including weeding and other measure were taken when necessary.

Artificial water chamber preparation

A brick water chamber (4×1.5×1) meter^3 was made to simulate waterlogging. Earthen pots with 30 days old plants were placed in the brick water chamber for 7 days to address waterlogging where water was kept almost to the pot's top 3-5 cm of soil.

Experimental design and treatments

The research was placed by two factors in Randomized Complete Block Design (RCBD) with three replications. Factor A: six blackgram varieties; V1-(BARI Mash-1), V_2-(BARI Mash-3), V_3-(DH-14), V_4-(RU-127), V_5 (DHL- 4) and V_6-(DHL-5) whereas factor B: Control (100% field capacity) and 7 days waterlogging condition.

Data collection and analysis

Various morpho-physiological, growth and yield-related parameters of blackgram were recorded. The chlorophyll content in leaf was quantified using a SPAD 502 chlorophyll meter. The SPAD value was collected from three leaves of each sampled plant at three different stages: the vegetative, blooming, and pod filling stage. Stress Tolerance Index (STI) was calculated according to Fernandez (1992): STI = $Ys \times Yp / (Yp)^2$

Yield index (YI) was calculated as follows:

$YI = (Ys)/(\bar{Y}s)$

Where, Ys and Yp are the yield of individual genotypes under stress and non-stress conditions, respectively; $\bar{Y}s$ is the average yield of all genotypes under stress conditions. The relative yield (RY) under waterlog condition was calculated as the yield of a specific genotype under waterlog divided by the highest yielding genotype in the population.

Collected data were statistically analyzed using Statistix 10 software package and the mean for every treatment were calculated. The ANOVA (analysis of variance) and difference between treatments were assessed by Least

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Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of waterlogging on growth, morphological, physiological and yield characteristics

Plant height (cm)

Waterlogging substantially impacts on the plant height of blackgram and the genotype DHL=4 (V5) exhibited a higher degree of tolerance to waterlogging conditions with maximum plant height (32.22 cm). Downward trends observed due to waterlogging, and the shortest plant height (23.50 cm) was acquired from BARI Mash-3. The differences in plant height could perhaps be attributed to the inherent genetic characteristics of different plant varieties, as well as the negative impacts resulting from prolonged exposure to waterlogged conditions over a period of 7-consecutive days.

In previous, a decrease in height observed in mungbean plant when subjected to flooding conditions was stated by Kyu *et al*. (2021) and Amin *et al*. (2017). In contrast, the aforementioned types exhibited heights of 28.50 cm, 23.50 cm, 29.93 cm, 25.70 cm, 32.22 cm and 27.5 cm, respectively, during a 7days of waterlogging (Table 1). We observed significant reductions across all genotypes were identified as being more sensitive to waterlogging. The plant height variation might be due to varietal characters of genotypes and adverse effects of continuous 7 days waterlogging condition. Waterlogging treatment resulted in a decrease in plant growth, namely in terms of leaf area and growth rate, across genotypes (Solaiman *et al.*, 2007; Pociecha *et al*., 2008; Celik and Turhan, 2011). In their study, Rana *et al*. (2019) reported a reduction in the height of blackgram plants when subjected to flooding conditions.

Table 1. Effects of waterlogging on plant height (cm) and number of branches of different genotypes of blackgram

Treatment	Variety					
	V_1	V_2	V_3	V_4	V_5	V_6
Control	31.16 bc	27.65 d	33.16 a	27.77 d	32.38 ab	27.97 d
Waterlogging	28.50 d	23.50 f	29.93 c	25.70 e	32.22 ab	27.5 d
CV	**2.74%**					
SE(±)	**0.64**					

Here, (V1=BARI Mash-1, V2=BARI Mash-3, V3=DH-14, V4=RU-127, V5=DHL-4, V6=DHL-5)

Number of branches plant^{-1}

Interaction effect of variety and treatments showed significant effect on number of branches plant^{-1} of blackgram. The highest number of branch per plant was noted in BARI Mash-1 (6) variety under control and the lowest was recorded in DHL- 5 (3) variety under waterlogging. Other varieties also showed significant difference in number of branch per plant according to control and waterlogging condition (Table 2). Nawata (1989) reported that the decrease in branch plant^{-1} could potentially be attributed to the competition for assimilates among the roots and other organs in waterlogged plants The outcome aligns with the observations made by Ghosh (2007), which indicated significant variations among different types in terms of the number of branches plant^{-1}. The presence of floods had a negative impact on the number of branches per plant in mungbean were previously describe by Zannat (2019) and Amin *et al*. (2016). The branching habit of a plant is genetically influenced and it was reduced expressively when plants were waterlogged for variable periods.

Number of leaves plant^{-1}

A considerable difference and negative impact of waterlogging was observed in terms of number of leaves per plant in blackgram plant (Table 3). BARI Mash-1 showed the highest number of leaves (11) in control condition but it showed less number of leaves (4) under waterlogging condition. The genotypes DHL-4 and DHL-5 showed the lowest number of leaves in waterlogging condition (Table 3). Alam (2022) in case of blackgram and Naher *et al.* (2019) in mungbean observed that the occurrence of short-term waterlogging have a significant impact on the variations in leaf count across all the different genotypes. Leaves exhibit a high susceptibility to waterlogging stress, as evidenced by alterations in leaf respiration, chlorophyll concentration, and photosynthetic assimilation during periods of waterlogging were previously observed (Parolin, 2000; Ansary (2007). In our study, plant discharge leaves for excessive water up taken because too much water results in soft and limp leaves in flooding conditions.

Leaf length (cm)

Significantly different lengths of leaves were found at the growth stages of Blackgram (Table 3). The highest leaf length (8.38 cm) was measured at control situation in DH-14 and lowest was measured in waterlogging condition BARI Mash-1 which was (6.05 cm). Other varieties were BARI Mash-3, RU-127, DHL-4, DHL-5 contained length of leaf respectively in control and treatment 6.72 cm and 7.72 cm; 8.05 cm and 8.5 cm; 7.94 cm and 9.22 cm; 7.72 cm and 7.83 cm (Table 3). Naher *et al*. (2022) and Islam (2005) observed the similar results in case of mungbean. In vegetative phase,

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leaf area growth was significantly different in cowpea plants that were waterlogged compared to those that were not by previously described (Umaharan *et al.*, 1997). Besides, plant leaves are also very receptive to waterlogging stress; respiration changes in the leaf, leaf chlorophyll content, and photosynthetic assimilation have been detected during a waterlogging period were mentioned by Parolin (2000). The changes might be due to the senescence and abscission of lower leaves at maturity stage.

Leaf width (cm)

Waterlogging condition adversely effect on the leaf width in blackgram plants. The highest leaf width (12.39 cm) was recorded at control situation in DHL-5 and lowest (5.22 cm) was noted in DHL-4 in waterlogging condition. The other varieties were BARI Mash-1, BARI Mash-3, RU-127, DH-14 which contained leaf width 11.21 cm and 6.80 cm; 11.52 cm and 7.78 cm; 11.99 cm and 6.18c m; 11.64 cm and 7.06 cm respectively in control and treatment (Table 3). It indicates that waterlogging decrease leaf width. Prolonged waterlogging decline the plant growth in terms of leaf area and growth rate in all the genotypes and the level of reduction was more pronounced in sensitive genotypes were previously described (Naher *et al.*, 2022; Solaiman *et al.*, 2007; Pociecha *et al.*, 2008; Celik and Turhan, 2011). Conversely, Bacanamwo and Purcell (1999) described that there was no correlation between leaf expansion in flooded plants and the accumulation of carbohydrates in the leaves.

Table 2. Effect of waterlogging on number of leaves, leaf length (cm) and leaf width (cm) plant-[1] of blackgram

Genotypes ×Treatment	Leaf number	Leaf length (cm)	leaf width (cm)
BARI Mash-1 × Control	11 a	6.72 bc	11.21 bc
BARI Mash-3 × Control	8 cd	6.72 bc	11.52 abc
DH-14 × Control	9 b	8.38 ab	11.64 ab
RU-127 × Control	8.33 bc	8.05 abc	11.99 ab
DHL- 4 × Control	7.33 d	7.94 abc	10.61 c
DHL-5 × Control	6.33 e	7.72 abc	12.39 a
BARI Mash-1 × Waterlogging	4.66 f	6.05 c	6.80 e
BARI Mash-3 × Waterlogging	5 f	7.72 abc	7.78 d
DH-14 × Waterlogging	4.66 f	8.72 ab	7.06 de
RU-127 × Waterlogging	5.00 f	8.5 ab	6.18 e
DHL- 4 × Waterlogging	3.66 g	9.22 a	5.22 f
DHL- 5 × Waterlogging	3.66 g	7.83 abc	6.64 e
CV %	**8.36**	**6.59**	**6.01**
SE(±)	**0.43**	**1.03**	**0.44**
LSD$_{(0.05)}$	**0.90**	**2.14**	**0.92**

Here, (V1=BARI Mash-1, V2=BARI Mash-3, V3=DH-14, V4=RU-127, V5=DHL-4, V6=DHL-5)

Chlorophyll content (SPAD unit)

Chlorophyll is the primary pigment that is essential for the process of photosynthesis. The presence of excessive water in the soil resulted in a decrease in the chlorophyll concentration within the leaf exhibited in Table 4. The recorded evidence of its susceptibility to flooding is apparent through the observable phenomenon of enhanced leaf yellowing. BARI Mash-3 exposed the highest concentration of chlorophyll in in both control (50.07) and waterlogging condition. The lowest level of chlorophyll content was observed in the DH-14 (29.53) under waterlogging conditions. The chlorophyll content rate decreased under the waterlogging-induced stress condition. The reduction in chlorophyll content resulted in the development of chlorosis in the leaves, which subsequently progressed to necrosis. Ultimately, these deleterious consequences ultimately led to the onset of senescence and subsequent mortality in the plant (Sairam *et al.*, 2002). In previous, Li *et al*. (2011) stated that waterlogging has a negative impact on photosynthetic parameters in pigeon pea. Both stomatal and non-stomatal components were found to impose limitations on

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photosynthesis under waterlogged conditions. Only the tolerant genotype demonstrated the ability to withstand the stress by comparatively preserving the chlorophyll content. This finding aligns with a previous study conducted by Ruchi *et al*. (2010) on blackgram, Naher *et al.* (2022) in mungbean member of the legume family. The current investigation revealed a correlation between vulnerability to waterlogging and a decrease in chlorophyll levels. The findings of Kumar *et al*. (2012) in mungbean and Bansal *et al.* (2015) in pigeon pea yielded a comparable outcome.

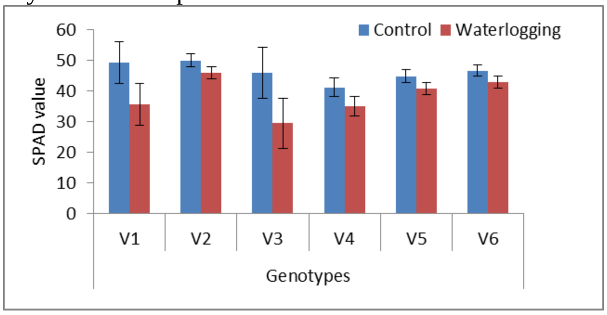

Figure 1. Effect of waterlogging on chlorophyll content of different genotypes of blackgram with CV% 5.15 and $LSD_{(0.05)}$ 3.69

Here, (V1=BARI Mash-1, V2=BARI Mash-3, V3=DH-14, V4=RU-127, V5=DHL-4, V6=DHL-5)

50% flowering plant^{-1}

Significant variations were detected between the control and the waterlogging group in terms of the delay in reaching 50% flowering (Table 7). BARI Mash-2 and BARI Mash-3 required lowest days (40) to flowering. BARI Mash-1 and the variety of DHL-4 required 47 days to 50% flowering in waterlogging condition. Nawata and Shigenaga (1988) described that the decrease in growth metrics exhibited a lesser magnitude during the flowering stage compared to the vegetative stage in yard long bean. Many plants exhibit indeterminate or determinate growth patterns, which remain consistent and unalterable. Conversely, there are other species that can be manipulated to deviate from their inherent flowering habits. Mungbean genotypes regardless of their tolerance or sensitivity to waterlogging, exhibited a suppression of flowering and pod formation were investigated by Kumar *et al*. (2013).

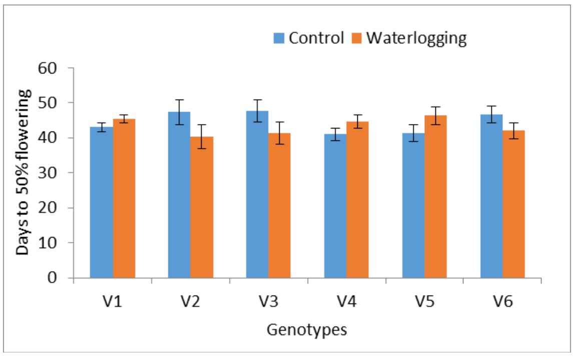

Figure 2. Effect of waterlogging on days to 50% flowering plant-^{1} of different genotypes of blackgram with CV% 3.79 and $LSD_{(0.05)}$ 2.81

Here, (V1=BARI Mash-1, V2=BARI Mash-3, V3=DH-14, V4=RU-127, V5=DHL-4, V6=DHL-5)

Root length after harvest

Blackgram varieties showed significant difference in root length due to waterlogging (Table 5). The longest root length (12.5 cm) was recorded in V_1=BARI Mash-1 in control and the shortest (8.3 cm) was observed from the same variety under waterlogging condition. The longest root was observed in DHL-4 at stress condition. Furthermore, some varieties had adventitious roots on day 7 after waterlogging. However, 14 days after water logging, leaves became yellow and some dried. Pourabdal *et al*. (2008) assumed that the swelling between the stem base and roots transports oxygen from shoots to roots. This adaptability aids air diffusion from shoot to roots were stated previously (Visser and Voesenek 2004). The weakening of the main root system helps to develop well adapted adventitious roots (Dat *et al*., 2006). The adventitious roots replace basal roots due to a morphological reaction to water-logging stress (Malik *et al*., 2001). When the basal root system failed, specialized roots then provide the water and minerals (Mergemann and Santor 2000; Steffens *et al*., 2006).

Root nodule number plant^{-1}

The nodule number of root in blackgram plants were not significantly different under waterlogging condition (Table 3). The highest number of root nodules (33.66) were obtained from control in variety BARI Mash-1 and lowest (26) nodules were found in BARI Mash-3 after waterlogging. Uddin *et al.* (2009) reported the similar result. Most of the legume crops are sensitive to waterlogging and show reduction in nodulation because the diffusion of oxygen into the nodule infection area is delicately regulated in response to several environmental cues and becomes sensitive to changes in the external rhizosphere oxygen tension were investigated previously (Roberts *et al*., 2010).

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Table 3. Effect of waterlogging on root length after harvest and root nodule number plant^{-1} of different genotypes of blackgram

Genotypes ×Treatment	Root length after harvest	Root nodule number
BARI Mash-1× Control	12.5 bc	33.66
BARI Mash-3 × Control	9.5 de	29.33
DH-14 × Control	11.16 cd	32
RU-127 × Control	9.83 de	29
DHL- 4 × Control	10.03 cde	29.66
DHL-5 × Control	11.66 cd	26.66
BARI Mash-1 × Waterlogging	8.3 e	31
BARI Mash-3 × Waterlogging	11.33 cd	26
DH-14 × Waterlogging	10.33 cde	33.33
RU-127 × Waterlogging	14.63 ab	29
DHL- 4 × Waterlogging	15.33 a	30
DHL- 5 × Waterlogging	9.4 de	26.66
CV %	**13.30%**	**9.81**
SE(±)	**1.21**	**2.37**
LSD$_{(0.05)}$	**2.51**	**NS**

Here, (V1=BARI Mash-1, V2=BARI Mash-3, V3=DH-14, V4=RU-127, V5=DHL-4, V6=DHL-5)

Pod number plant^{-1}

The presence of waterlogging conditions led to a considerable decrease in the quantity of pods produced per plant (Table 4). The control group in variety V4=RU-127 yielded the largest number of pods per plant, with a count of 16. The cultivar V5=DHL-4 had the lowest pod count (7) per plant following waterlogging. According to Islam (2005), the phenomenon of waterlogging had a substantial negative impact on the number of pods per plant in Mungbean. The study found that control plants produced 36% more pods compared to plants that experienced waterlogging. Islam (2008) stated the occurrence of waterlogging had a substantial negative impact on the number of pods per plant in mungbean. The study found that control plants, which were not subjected to waterlogging, produced 36% more pods compared to the waterlogged plants. In previous, several researcher documented the waterlogging stress in in different pulse crop (Alam, 2022; Zannat 2019; Solaiman *et al*., 2007 and Pociecha *et al*., 2008).

Pod length (cm)

The length of pods is a significant trait that contributes to the overall output in blackgram cultivation. The observed varieties exhibited a statistically significant variation in pod length (Table 4). The maximum pod length observed in the experimental group V_6=DHL- 5 was 8.11 cm. The V_5=DHL-4 treatment exhibited the shortest pod length, measuring 5.95 cm, under waterlogging conditions. One potential explanation for this findings may lie in the genetic composition of the respective cultivars. The pod length of different types of blackgram plants exhibited a decrease when subjected to a waterlogging situation for duration of seven days waterlogging. The length of mungbean pods was found to be considerably influenced by waterlogging stress was observed by Islam (2003).

Table 4. Effect of waterlogging on pod number and pod length plant^{-1}, number of seed per pod, hundred seed weight of

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different genotypes of blackgram

Genotypes ×Treatment	Pod number/plant	Pod length (cm)	Number of seed per pod	Hundred seed weight g)	Yield (g/plant)
BARI Mash-1× Control	12 c	6.28 e	6.00	2.46	6.61 a
BARI Mash-3 × Control	10 d	7.83 abc	4.33	2.46	2.45 d
DH-14 × Control	14 b	7.95 ab	4.67	2.99	4.46 bc
RU-127 × Control	16 a	6.88 d	4.33	2.81	1.31 e
DHL- 4 × Control	14 b	7.78 abc	5.67	2.80	5.25 b
DHL-5 × Control	12 c	8.11 a	4.67	2.36	1.69 de
BARI Mash-1 × Waterlogging	9 de	6.06 e	4.67	3.11	5.04 b
BARI Mash-3 × Waterlogging	7 fg	7.55 bc	3.33	2.33	4.58 bc
DH-14 × Waterlogging	8 ef	7.46 c	3.33	2.00	3.81 c
RU-127 × Waterlogging	12 c	6.41 de	2.67	2.48	1.58 e
DHL- 4 × Waterlogging	7 g	5.95 e	3.67	3.00	1.45 e
DHL- 5 × Waterlogging	8 efg	6.3 e	3.00	2.81	1.59 e
CV %	**7.37%**	**3.96%**	**14.02**	**10.63**	**14.86**
SE(±)	**0.66**	**0.22**	**0.48**	**0.22**	**6.61 a**
$LSD_{(0.05)}$	**1.38**	**0.47**	**NS**	**NS**	**2.45 d**

Here, (V1=BARI Mash-1, V2=BARI Mash-3, V3=DH-14, V4=RU-127, V5=DHL-4, V6=DHL-5)

Number of seed per pod

Waterlogging resulted in a decrease in the seed count per pod in various blackgram cultivars compared to control (Table 4). The variety with the maximum number of seeds (6.0) per pod was V_1=BARI Mash-1while lowest number of seeds were recorded in V_2=BARI Mash-3 and V4=RU-127 (Table 4). Previous studies have reported similar results in winter rape (Zhou *et al*., 1997) and green gram (Laosuwan *et al*., 1994; Ahmed *et al*., 2002). There was significant variation observed in the number of seeds per pod across different genotype

Hundred seed weight (g)

There were no significant variations observed on the 100-seed weight in different blackgram plants due to short-term flooding (Table 4). The DH-14 genotype had the maximum hundred seed weight (2.99 g) under control conditions. Conversely, the BARI Mash-1 variety revealed the highest measured of 100-seed weight (3.11 g) when subjected to waterlogging stress. In their study, Nawata *et al*. (1991) observed a decrease in the weight of one hundred seeds of yard long bean due to waterlogging treatments. The smallest seed weight was observed in plants that were continuously treated to waterlogging. The decreased size of the seeds could be attributed to the likely occurrence of inadequate translocation of assimilates from the source to the sink. The variables of 100-seed weight, plant height, and days to maturity were found to be controlled by additive gene activity were described by Gupta *et al*. (1978). Several researchers have all documented comparable results in their respective studies (Sarkar and Banik, 1991; Katial and Shah, 1998; Raj and Tripathi, (2005).

Yield (g /plant)

Blackgram yield per plant was considerably influenced by flooding condition (Table 7). In control condition, BARI Mash-1 exhibits the highest yield (6.61 g) followed by DHL-4, DH-14, BARI Mash-3, DHL- 5, and RU-127 (Table 4). In contrast, BARI Mash-1 exhibited the highest yield per plant (5.04g) compared to other varieties, with a relatively minimal reduction in yield under waterlogging conditions. Likewise, BARI Mash-3 variety revealed a significant decrease in yield per plant (4.58 g) particularly under waterlogging conditions. The primary cause for the decrease in seed yield was mostly attributed to the compromised

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capacity of the plants to absorb water or the hindrance of synthesis and transportation of photosynthetic assimilate were mentioned previously (Kumar *et al*., 2013). The yield loss may vary between 15% and 80% due to by waterlogging depended stress, crop species and growth stage and soil type were recorded by Wang *et al*. (2013). Waterlogging caused a drastic reduction in dry matter and seed yield in mungbean, however, genotypes showed variable response to waterlogging was previously stated by Jahan and Ahmed (2023). In contrary, Palta *et al*. (2010) documented that the presence of waterlogging resulted in enhancements in the quantity of pods, the rate of photosynthesis, and the accessibility of plant nitrogen, ultimately leading to improved output in cultivars that exhibited resistance.

Stress tolerance index (STI), yield index (YI) and relative yield (RY)

Table 5 showed that th**e** highest STI was found in BARI Mash-3 (V2) followed by V4, V6, V3, V1 and the lowest was found in V5. On the other hand highest YI was found in BARI Mash-1 (V1) followed by V2, V3, V4 and V6. The lowest yield index was found in V5.

Table 5. Stress tolerance index (STI), yield index (YI) and relative yield (RY) of blackgram genotypes under normal and waterlogging condition

Genotypes	Seed yield g/plant		Index	
	Normal (Yp)	Waterlogged (Ys)	STI	YI
V1	6.61	5.04	0.76	1.67
V2	2.45	4.58	1.87	1.52
V3	4.46	3.81	0.85	0.85
V4	1.31	1.58	1.21	0.52
V5	5.25	1.45	0.28	0.48
V6	1.69	1.59	0.94	0.53

Here, (V1=BARI Mash-1, V2=BARI Mash-3, V3=DH-14, V4=RU-127, V5=DHL-4, V6=DHL-5)

CONCLUSION

All the growth, yield and physiological traits of blackgram plants resulting decreased under waterlogging compared to control condition. In conclusion, plant height, leaf number, leaf length and chlorophyll content reduced significantly due to waterlogging compared to control. Waterlogging-induced stress decreased the seed yield significantly than the control. BARI Mash-1 provided the highest yield (5.04g) per plant and yield index (1.67) than other varieties under waterlogging stress. Stress tolerance index was maximum in BARI Mash-3. Therefore, BARI Mash-1 and BARI Mash-3 were performed better comparing to other genotypes. The BARI Mash-1 variety was more waterlogging stress tolerant than other genotypes and it can be used to improve tolerance of blackgram to waterlogging and be added in the existing cropping pattern at short term waterlogging condition in Bangladesh.

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Conflict of Interest

There are no conflicts of interest declared by the authors.

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