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EFFECT OF DROUGHT STRESS ON PHOTOSYNTHESIS, STOMATAL CONDUCTANCE, TRANSPIRATION AND YIELD OF MUNGBEAN GENOTYPES UNDER HIGH TEMPERATURE

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Abstract

Climate is changing and air temperature is rising due to increasing concentration of CO_2 and other atmospheric greenhouse gases. Drought is one of the most prevalent forms of abiotic environmental stress that reduce crop productivity. An experiment was conducted with six mungbean (*Vigna radiata* L. Wilczek) mutants *viz*., MI-12, MM-1, MM-11, MM-2, MM-5, MM-8 along with Binamoog-8 at Bangladesh Institute of Nuclear Agriculture during March-May, 2021 to assess the effect of drought at flowering stage of the mungbean genotypes under high temperature. Plants were grown in ambient temperature and during flowering stage those were kept in plant growth chamber at 38 ^{0}C for 24 hrs under different soil moisture levels (80, 60 and 40% FC) in pot soil. After high temperature treatment, the plants were allowed to complete the maturity under sufficient soil moisture (80% FC) at ambient temperature. The experiment was laid out in a randomized complete block design with three replications. Data on photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance, transpiration were recorded during stress imposition and yield and yield attributes were recorded at maturity. Under the temperature treatment photosynthesis, Fv/Fm, stomatal conductance, transpiration rate, water use efficiency and yield decreased significantly with the decrease of soil moisture levels. Photosynthesis, Fv/Fm, stomatal conductance, transpiration rate water use efficiency and yield decreased 10.10, 2.35, 7.40, 3.24, 7.16 and 34.87, respectively at 60% FC and 14.35, 7.05, 18.51, 10.81, 15.30 and 62.73%, respectively, at 40% FC compared to control. The mutants MM-5 and MM-8 showed better performance under drought and high temperature.

Key words: Drought, temperature, photosynthesis, Fv/Fm, stomatal conductance, transpiration, water use efficiency, mungbean yield

Introduction

Drought is a multidimensional complex stress, simultaneously disturbing the physiological, morphological, biochemical, and molecular states which control the growth and quality of the crop and ultimately crop productivity (Basu *et al*., 2016). This situation has been aggravated worldwide as drought-stressed areas are expanding rapidly due to uneven rainfall, limited water sources, and other rapid and drastic changes in global environmental conditions (Fahad *et al*., 2017). Mungbean (*Vigna radiata* L. Wilczek) is one of the most important crops of global economic importance. The raw and mature seeds are rich in nutrients including carbohydrates, protein, fibers, minerals, antioxidants

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like flavonoids (Quercetin-3-Oglucoside), and phenolics (Guo *et al*., 2012). In addition to being the prime source of human food and animal feed, it plays an important role in maintaining the soil fertility by enhancing the soil physical properties and fixing atmospheric nitrogen (Naik *et al*., 2020). Despite being an economically important crop, overall production of mungbean is low (838 kg ha^{-1}) (BBS, 2021) due to abiotic and biotic stresses (Islam *et al*., 2006; Bangar *et al*., 2018). It has raceme type of inflorescence with asynchronous flowering. The number of fruits with developing seeds increases after fruit setting stage and reaches to maximum seed growth stage but during this period the plant is still growing vegetative. Therefore, developing reproductive sinks are competing for assimilates with vegetative sinks. Number of fruits and seeds is related with photosynthetic rate that determines through leaf area and dry matter production (Islam and Razzaque, 2010). Per cent solar radiation interception and rate of dry matter production increased with leaf area development (Hamid *et al*., 1990). Mungbean yield is predetermined by the potential of a given variety and the environment. Pulse crops are generally cultivated during the dry season, when water deficit or unavailability of soil moisture is a common occurrence (Islam *et al*., 2005; Islam and Razzaque, 2007). Soil moisture is an essential requirement which regulates physiological growth processes and yield of plants. However, different crop cultivars have different ability to respond to drought conditions in terms of growth and development. Amelioration of drought environment through management practices like irrigation, mulching etc. are costly involvement and sometimes quite impossible for the poor economic conditions of the farmers. The best alternative is thus developing/screening of drought tolerant cultivars for the moisture deficit areas of the country. However, mungbean varieties respond variably to drought stress depending on stress duration, growth stage, and variety of the crop. Optimum temperature for potential yield of mungbean lies between 28-30^{o}C (Poehlman l99l). High temperature (36^{o}C) at pre-flowering and flowering stages decreases photosynthetic rate, biomass and yield in mungbean (Islam 2018 and Islam 2015). Increases in temperature resulted in changes in the fluorescence parameters in two varieties of beans, but to a different extent (Pastenes and Horton 1996). In Bangladesh, summer mungbean is generally cultivated in March-May and high temperature (34-38 ^{o}C) often affects its growth and yield. But information regarding their tolerance to high temperature is less. When physiological basis of yield and yield-forming components under drought and temperature stress are understood, it is possible to improve yields of a mungbean crop. So, effect of drought on seven mungbean genotypes under high temperature was investigated with respect to photosynthetic related parameters and yield.

Materials and methods

A pot experiment was conducted at the pot yard of the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh. The experimental site falls under the AEZ (Agro-Ecological-Zone)-9 (Old Brahmaputra Floodplain) of Bangladesh and situated at latitude 24.75°N and longitude of 90.50°E. The soils of the experiment were collected from the field of BINA Farm. The top soil was non-calcareous Dark Grey

Floodplain with loamy texture belonging to the AEZ Old Brahmaputra Floodplain. The collected soil was pulverized, inert materials, visible insect pest and plant propagules were removed. Pots are filled with top soils. The pot was 25 cm deep with 27 cm diameter at the top. The soil moisture stresses were calculated based on field capacity (FC). Gravimetric Method determined FC. FC of the soil was treated as 100% FC and 80% of FC (control), 60 and 40% were used as drought stress. Each pot contained 12 kg soil. All soils pots were fertilized with Urea, TSP and MoP @ 0.40, 0.70 and 0.40 g pot^{-1} corresponding @ 40, 70 and 40 kg ha^{-1}, respectively. All fertilizers were applied as basal dose. The experiment was carried out with six mutants *viz*., MI-12, MM-1, MM-11, MM-2, MM-5, MM-8 along with Binamoog-8 of mungbean. Seeds were sown in pots on first March 2021. Five seeds were sown in each pot and finally one plant was allowed to grow for treatment imposition and data collection. The experiment was set in a two factorial RCBD with three replications. The first factor was mungbean genotypes and the second factor was irrigations: control (80% FC) and drought (60 and 40% FC) stress treatments. Cultural practices were followed as and when required. Plants were grown in ambient temperature and during flowering stage those were kept in plant growth chamber at 38 ^{0}C for 24 hrs under different soil moisture levels (80, 60 and 40% FC) in pot soil. Then all the plants were allowed to complete the maturity under sufficient soil moisture (80% FC) at ambient temperature. Data on photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance and transpiration and water use efficiency were recorded from 9 plants of each genotype during stress imposition using Portable Photosynthesis System (Li-6800, LI-COR, USA). At maturity, data on plant height, pods plant^{-1}, seeds pod^{-1}, 1000-seed weight and seed weight plant^{-1} were recorded. Statistical analysis was done and DMRT test adjusted the means.

Results and Discussion

Results revealed that photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance, transpiration rate and water use efficiency of mungbean genotypes decreased with the decrease of soil moisture levels under high temperature at flowering stage (Table 1-2). Under the temperature treatment photosynthesis, Fv/Fm, stomatal conductance, transpiration rate and water use efficiency decreased 10.10, 2.35, 7.40, 3.24 and 7.16%, respectively at 60% FC and 14.35, 7.05, 18.51, 10.81 and 15.30% respectively, at 40% FC compared to control. The results are in consistent with Islam 2018 and Islam 2015. The highest values of plant height, yield and yield attributes were found in control condition (80 %FC) and those were gradually decreased at 60 and 40 %FC (Table 3-4). Under the temperature treatment plant height, pods plant^{-1}, seed pod^{-1}, 1000-seed weight and seed yield plant^{-1} decreased 7.31, 5.65, 20.72, 15.28 and 34.87%, respectively at 60% FC and 19.11, 27.38, 37.07, 20.93 and 62.73%, respectively at 40% FC compared to control. The results revealed that yield and yield contributing characters decreased severely with the increasing level of water stress. The results are in conformity with Singh and Singh 2011; Pooja *et al*. 2019; Kumar *et al*. 2020. The seed yield of mungbean crop is a function of cumulative effect of various yield components, which are influenced by the genetic make-up of variety, various agronomic practices, and environmental conditions (Yuliasti and Reflinur, 2015). Drought stress is considered as one of the most devastating environmental stresses affecting crop production globally. Mungbean grows mainly in rain-fed conditions at high temperatures (27-30 ^oC), with low humidity and moderate rainfall from 60 to 80 cm (Kumar *et al*. 2020). Due to this, it faces stress at different development stages and it thrives under drought conditions. Morpho-physiological parameters, yield attributes and yield of mungbean genotypes significantly decrease with drought stress (Islam *et al*. 2005; Islam *et al*. 2006; Sunayana *et al*. 2016). High temperature disrupts water, ion and organic solute movement across plant membranes which interfere with photosynthesis and respiration. High temperature stress causes direct negative impact on flower retention in mungbean (flower shading up to 79%) and consequently on pod formation (Kumari and Verma, 1983). Photosynthesis, stomatal conductance, stem weight, total dry matter production and yield decrease with high temperature (36^{o}C) at pre-flowering, flowering and pod filling stage of mungbean genotypes (Islam, 2015; Islam, 2018). Although mungbean yield is not always directly related with photosynthesis, however, related with leaf area and total dry matter production and high yielding mutants may have higher photosynthesis with higher water use efficiency (Islam and Razzaque, 2010). Decreased plant height under stress might be due to lower cell division under stress condition. The highest yield in control was due to higher number of pods plant^{-1}, seeds pod^{-1} and seed size (1000-seed weight). The mungbean genotypes responded variably to drought stress. The genotypes MM-8 and MM-5 had higher values in most of the photosynthetic parameters and yield.

Table 1. Effect of water stress on photosynthesis, Fv/Fm, stomatal conductance, transpiration and water use efficiency of mungbean genotypes under high temperature

Treatment	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Fv/Fm	Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$)	Transpiration ($mmolH_2Om^{-2}s^{-1}$)	Water use efficiency
Control	26.33 a	0.85 a	0.27 a	3.70 a	7.12 a
60 %FC	23.67 b	0.83 b	0.25 b	3.58 b	6.61 b
	(10.10)	(2.35)	(7.40)	(3.24)	(7.16)
40 %FC	19.95 c	0.79 c	0.22 c	3.30 c	6.03 c
	(14.35)	(7.05)	(18.51)	(10.81)	(15.30)
CV (%)	4.20	2.60	2.78	0.77	4.04
Genotype					
Binamasur-8	22.67 cd	0.80 b	0.25 b	3.51 c	6.43 cd
MI-12	22.00 d	0.80 b	0.23 d	3.47 d	6.32 d
MM-1	23.22 c	0.82 b	0.24 bc	3.50 c	6.61 c
MM-11	21.89 d	0.80 b	0.24 cd	3.52 c	6.19 d
MM-2	22.00 d	0.81 b	0.24 bc	3.47 d	6.32 d
MM-5	24.67 b	0.87 a	0.26 a	3.59 b	6.86 b
MM-8	26.78 a	0.85 a	0.27 a	3.63 a	7.38 a
CV (%)	4.20	2.60	2.78	0.77	4.04

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Table 2. Combined effect of water stress and mungbean genotypes on photosynthesis, Fv/Fm, stomatal conductance, transpiration and water use efficiency under high temperature

Genotype×Treatment	Photosynthesis ($\mu molCO_2m^{-2}s^{-1}$)	Fv/Fm	Stomatal conductance ($mmolH_2Om^{-2}s^{-1}$)	Transpiration ($mmolH_2Om^{-2}s^{-1}$)	Water use efficiency
Binamasur-8×Control	26.00 bcd	0.82 efg	0.27 bc	3.70 bc	7.03 cd
Binamasur-8×60% FC	23.00 ghi (11.53)	0.82 efg (0)	0.25 efg (7.40)	3.58 ef (3.24)	6.42 ef (8.67)
Binamasur-8×40% FC	19.00 jk (26.92)	0.76 i (7.31)	0.22 i (18.51)	3.25 i (12.16)	5.85 ghi (16.78)
MI × Control	25.33 de	0.82 efg	0.26 def	3.66 cd	6.93 cd
MI-12 × 60% FC	22.33 hi (11.84)	0.81 efg (1.21)	0.24 h (7.69)	3.53 g (3.55)	6.33 ef (8.65)
MI-12 × 40% FC	18.33 jk (27.63)	0.77 hi (6.09)	0.21 i (19.23)	3.22 i (12.02)	5.69 hi (17.89)
MM-1 × Control	26.33 bcd	0.87 bc	0.27 bcd	3.70 bc	7.12 bc
MM-1 × 60% FC	23.67 fgh (10.10)	0.81 efg (6.89)	0.25 fgh (7.40)	3.55 fg (4.05)	6.66 de (6.46)
MM-1 × 40% FC	19.67 j (25.29)	0.77 hi (11.49)	0.22 i (18.51)	3.26 i (11.89)	6.04 fgh (15.16)
MM-11 × Control	25.67 cde	0.81 efg	0.26 cde	3.71 b	6.92 cd
MM-11 × 60% FC	22.00 i (14.29)	0.82 efg (0)	0.24 gh (7.69)	3.59 ef (3.23)	6.13 fg (11.41)
MM-11 × 40% FC	18.00 k (29.87)	0.77 hi (4.93)	0.21 i (19.23)	3.26 i (12.12)	5.52 i (20.23)
MM-2 × Control	25.33 de	0.83 def	0.27 bcd	3.65 d	6.94 cd
MM-2 × 60% FC	22.33 hi (11.84)	0.82 efg (1.20)	0.25 fgh (7.40)	3.51 g (3.83)	6.36 ef (8.35)
MM-2 × 40% FC	18.33 jk (27.63)	0.79 ghi (4.81)	0.22 i (18.51)	3.24 i (11.23)	5.65 hi (1.29)
MM-5 × Control	27.00 bc	0.91 a	0.28 ab	3.70 b	7.29 abc
MM-5 × 60% FC	25.00 def (7.40)	0.86 cd (5.49)	0.27 bcd (3.57)	3.63 de (1.89)	6.89 cd (5.48)
MM-5 × 40% FC	22.00 i (18.51)	0.84 cde (7.69)	0.25 fgh (10.71)	3.43 h (7.29)	6.41 ef (12.07)
MM-8 × Control	28.67 a	0.90 ab	0.28 a	3.77 a	7.60 a
MM-8 × 60% FC	27.33 ab (4.67)	0.86 bcd (4.44)	0.27 ab (3.57)	3.65 d (3.18)	7.49 ab (1.44)
MM-8 × 40% FC	24.33 efg (15.13)	0.80 fgh (11.11)	0.25 efg (10.71)	3.46 h (8.22)	7.03 cd (7.50)
CV (%)	4.20	2.60	2.78	0.77	4.04

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Table 3. Effect of water stress on yield and yield components of mungbean genotypes under high temperature

Treatment	Plant height (cm)	Pods plant^{-1}	Seed pod^{-1}	1000-seed wt. (g)	Seed wt. plant^{-1} (g)
Control	47.04 a	15.74 a	10.52 a	39.27 a	6.28 a
60% FC	43.60 b	14.85 b	8.34 b	33.31 b	4.09 b
	(7.31)	(5.65)	(20.72)	(15.28)	(34.87)
40% FC	38.05 c	11.43 c	6.62 c	31.05 c	2.34 c
	(19.11)	(27.38)	(37.07)	(20.93)	(62.73)
CV (%)	6.30	9.06	5.29	1.96	10.21
Genotypes					
Binamasur-8	43.62 b	12.08 c	9.14 b	30.26 f	3.46 c
MI-12	48.69 a	13.20 c	8.07 cd	38.96 b	4.40 b
MM-1	44.33 b	14.42 b	7.48 e	39.78 a	4.37 b
MM-11	42.62 b	10.76 d	8.36 c	35.06 d	3.37 c
MM-2	36.64 c	12.56 c	7.80 de	33.38 e	3.47 c
MM-5	42.33 b	14.56 b	9.76 a	38.01 c	5.49 a
MM-8	42.02 b	20.49 a	8.87 b	26.38 g	5.09 a
CV (%)	6.30	9.06	5.29	1.96	10.21

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Table 4. Combined effect of water stress on yield and yield attributes of mungbean genotypes under high temperature

Interaction	Plant height (cm)	Pods plant^{-1}	Seed pod^{-1}	1000-seed weight (g)	Seed weight plant^{-1} (g)
Binamasur-8 × Control	47.87 bc	13.07 ef	11.10 ab	32.97 ij	4.78 ef
Binamasur-8 × 60% FC	44.00 cde	13.07 ef	9.00 efg	30.17 lm	3.54 gh
	(8.08)	(0)	(18.91)	(8.49)	(25.94)
Binamasur-8 × 40% FC	39.00 fghi	10.10 gh	7.33 j	27.63 n	2.05 jk
	(18.52)	(22.72)	(39.96)	(16.19)	(57.11)
MI × Control	54.73 a	14.87 cde	9.87 cd	44.97 a	6.59 c
MI-12 × 60% FC	48.67 b	14.87 cde	8.00 hik	37.57 ef	4.46 f
	(11.07)	(0)	(18.94)	(16.45)	(32.32)
MI-12 × 40% FC	42.67 defgh	9.87 h	6.33 k	34.33 gh	2.14 jk
	(22.03)	(33.62)	(35.86)	(23.66)	(67.52)
MM-1 × Control	49.13 b	13.40 def	9.70 cde	45.50 a	5.90 cd
MM-1 × 60% FC	46.20 bcd	16.20 c	7.73 ij	38.40 de	4.79 ef
	(5.96)	(0)	(22.30)	(15.60)	(18.81)
MM-1 × 40% FC	37.67 i	13.67 def	5.00 l	35.43 g	2.42 ij
	(23.32)	(0)	(48.45)	(22.13)	(58.98)
MM-11 × Control	46.87 bcd	12.07 fg	10.40 bc	41.07 c	5.17 ef
MM-11 × 60% FC	43.33 def	12.07 fg	8.33 ghi	33.27 hi	3.35 gh
	(7.55)	(0)	(19.90)	(18.99)	(35.20)

Table 4. Continued.

Interaction	Plant height (cm)	Pods plant^{-1}	Seed pod^{-1}	1000-seed weight (g)	Seed weight plant^{-1} (g)
MM-11 × 40% FC	37.67 i (19.62)	8.13 h (32.64)	6.33 k (39.13)	30.83 kl (24.93)	1.60 k (69.05)
MM-2 × Control	40.27 efghi	13.73 def	10.07 cd	39.10 d	5.36 de
MM-2 × 60% FC	37.33 i (7.30)	13.93 def (0)	8.00 hij (20.55)	31.93 jk (18.33)	3.52 gh (34.32)
MM-2 × 40% FC	32.33 j (19.71)	10.00 gh (27.16)	5.33 l (47.07)	29.10 m (25.57)	1.53 k (71.45)
MM-5 × Control	45.33 bcd	15.33 cd	11.27 a	43.73 b	7.54 b
MM-5 × 60% FC	43.00 defg (5.14)	15.33 cd (0)	9.33 def (17.21)	36.70 f (16.07)	5.24 de (30.50)
MM-5 × 40% FC	38.67 ghi (14.69)	13.00 ef (15.19)	8.67 fgh (23.07)	33.60 hi (23.16)	3.67 g (51.32)
MM-8 × Control	45.07 bcd	27.73 a	11.27 a	27.53 no	8.59 a
MM-8 × 60% FC	42.67 defgh (5.32)	18.50 b (33.28)	8.00 hij (29.01)	25.17 p (8.57)	3.72 g (56.69)
MM-8 × 40% FC	38.33 hi (14.95)	15.23 cd (45.07)	7.33 j (34.96)	26.43 o (3.99)	2.95 hi (65.65)
CV (%)	6.30	9.06	5.29	1.96	10.21

Values having common letter(s) in a column do not differ significantly at 5% level as per DMRT.
Figures within parenthesis indicate % decrease at 60 and 40% FC compared to control.

Conclusion

Photosynthesis, Fv/Fm (maximum quantum efficiency of PSII photochemistry), stomatal conductance, transpiration rate, water use efficiency and yield of mungbean genotypes decreased with the decrease of soil moisture levels under high temperature at flowering stage. Among the mungbean genotypes, MM-5 and MM-8 showed better performance under drought and high temperature. So, these two mutants may be used for cultivation under drought and high temperature stress.

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