Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2024) 6 (1) : 91-100

PERFORMANCE OF MUNGBEAN WITH ELEVATED NPKS NUTRITIONS UNDER WATER STRESS

Shafayet Ahammad Siddiqui[1], Apple Mahmud[2], Qazi A. Khaliq[2], Md. Moynul Haque[2], ARM Solaiman[3], Mohammad Moziball Hoque[4], Rinki Akter[4] and Md. Abdul Karim[2,5]

[1]Deputy Director, Department of Agricultural Extension (DAE), Bangladesh;[2]Department of Agronomy and [3]Department of Soil Science, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh; [4]Solidaridad Network Asia, House# 32, Road 10A, Dhanmondi, Dhaka-1209, Bangladesh; [5]College of Agricultural Sciences, International University of Business Agriculture and Technology, Uttara Model Town, Dhaka, Bangladesh.

Corresponding email: akarim1506@gmail.com

Received: 03 June 2024, revised: 11 June 2024, accepted: 13 June 2024, DOI: https: //doi.org/10.59619/ej.6.1.11

ABSTRACT

Drought is one of the most serious environmental stresses that hinders mungbean (*Vigna radiata* L.) production seriously. Improvement of soil nutrition is one of the effective measures to enhance drought tolerance of upland crops like mungbean. This study was conducted to evaluate the effect of higher levels of macro nutrients on growth and yield performance of mungbean. Recommended dose, and two, three and four folds of the recommended dose of major fertilizers (N-P-K-S) were applied on two popular mungbean varieties namely, Binamoog-5 and BU mug4 under water stress. The effect of the higher levels of fertilizer on stressed plants was evaluated by examining different morphological parameters of growth such as plant height, parameters of growth analyses, yield attributes and grain yield. Water stress in general had a negative effect on plant growth and development. However, the enhanced levels of nutritions lessened the water stress effect. Increased plant height, leaf area, CGR, RGR, NAR, and grain yield and yield attributes were measured in plants that received elevated nutrients. In general Binamoog-5 showed higher water stress tolerance than BU mug4 in relation to the production of grain yield and yield attrbutes. Under water stress the highest number of pods plant^{-1} was recorded in T_4 where Binamoog-5 produced 15.33 plant^{-1} and BU mug4 had 13.33 plant^{-1}. The highest 100-seed weight was recorded in Binamoog-5 (4.65 g) and BU mug4 had 4.29 g with the three-fold increased doses of N-P-K-S fertilizer (T_4). The highest grain yield plant^{-1} was also recorded in T_4 where Binamoog-5 produced 4.95 g plant^{-1} and BUmug4 produced 3.95 g plant^{-1}. It was concluded that higher levels of NPKS enhanced productivity of mungbean, than the recommended.

Keywords: Greengram, nutrients, seed yield

Introduction

Mungbean (*Vigna radiata* L.) is a short-duration grain legume which is regarded as a very nutritious summer legume in Bangladesh. It has high content of easily digestible proteins (20–32%), carbohydrates (53.3–67.1%), lipids (0.71–1.85%), vitamins, minerals, and fiber (Mehta *et al*. 2021). It also contains remarkable quantity of ascorbic acid, riboflavin, digestibility and flavor (Azadi *et al*. 2013). Besides high protein, it has abundant symbiotic root rhizobia to fix atmospheric nitrogen, which enhances soil fertility (Baroowa and Gogoi 2015). Bangladesh has an ideal agro-ecological condition for growing this crop. It is grown in 46117.06 hectares with a production of 41548.48 metric tons, and the area under pulse crop is 374892.9 hectares with a production of 432487.1 metric tons (BBS 2022). Mungbean can be grown in three seasons in a year in Bangladesh, but it is usually sown at the end of January to mid February, when it is mostly dry for the unpredictable or little rainfall (Islam *et al.* 2020).

Water is one of the major components of plant cells. Shortage of water induces a series of physiological, biochemical and morphological changes in crops leading to drastic loss in yield (Abbasi *et al.* 2014).Water stress inhibits linear growth of plants, reduce leaf number per plant and individual leaf size, leaf longevity and dry matter accumulation by decreasing the soil's water potential (Anjum *et al.* 2011). Deficiency in soil moisture suppresses the rate of photosynthesis by decreasing leaf

area, causing leaf abscission, changes in chlorophyll content, affecting chlorophyll components, damaging the photosynthetic apparatus and uptake of nutrient in greengram (Manivannan *et al.* 2007). Water stress also impacts crop phenology, leaf area development, blooming, pod setting and finally leads to reduced yield. Plants that experience water stress at different phases of growth undergo morpho-physiological changes to acclimatize in such conditions (Ali *et al.* 2011). It has been observed that water stress at the reproductive stage, particularly during blooming and pod development, significantly reduces mungbean production (Mahajan *et al.* 2023).

To sustain mungbean production, the detrimental effects of water stress on morpho-physiology and yield of mungbean need to be minimized. Plants develop a wide range of adaptive mechanisms to maintain productivity and ensure survival under drought stress conditions. Eventhough plants have an internal resilience to drought stress, the detrimental effects of drought can be reduced by an appropriate and balanced supply of mineral nutrients (da Silva *et al.* 2011, Waraich *et al.* 2011). Plant mineral-nutrient contributes significantly to increase plant tolerence to drought stress (Khan *et al.* 2023). Plants need six major macro minerals, such as nitrogen (N), phosphorous (P), potassium (K), magnesium (Mg), sulfur (S), and calcium (Ca) along with micronutrient minerals covering iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), and molybdenum (Mo) that are essential for driving plant growth and development (Kirkby *et al.* 2023). However, the uptake of most of the mineral nutrients is decreased under abiotic stresses (D'Oria *et al.* 2022). Nutrients act as an integral component of the plant system that play a significant role in coordinating several physiological and developmental aspects in plants such as seed germination, root and shoot growth, photosynthesis, respiration, as well as flower development (Saleem *et al.* 2023, Giri *et al.* 2017). Elevated doses of recommended fertilizers may play an important role in mitigating the detrimental effects of water stress in mungbean. This experiment was, therefore, carried out to evaluate the effects of elevated nitrogen, phosphorus, potassium and sulphur fertilization on morphology, growth and yield of mungbean under water stress.

Materials and Methods

Experiment was carried out in a vinylhouse of the Department of Agronomy, Bangabandhu Sheikh MujiburRahman Agricultural University, Salna, Gazipur. The experimental site is situated in the sub tropical region characterized by heavy rainfall during the months from July to September and scanty or no rainfall in rest of the year. The soil used in the pot belongs to Salna series of Shallow Red-Brown Terrace soil type (AEZ 28) with silty clay in surface and silty clay loam in sub-surface region (Brammer 1971). Plastic pots of 30 cm in diameter and 24 cm in height were used in this experiment. Plastic pots were filled with 14 kg air-dried soil mixed with cowdung at a ratio of 4:1. The pot soil was fertilized with 0.20g, 0.80g, 0.40g and 0.20g of Urea, TSP, MoP and Gypsum @) 15.5-25.5-30.5-15.5 kg N-P-K-S per hectare, respectively (FRG 2012). Except half of urea the other fertilizers including the enhanced doses of N-P-K-S were estimated and applied as basal, and the rest half of urea was applied at 25 DAE.

The experiment was laid out in a RCBD factorial design with three replications.Two popular varieties Binamoog-5 and BU mug4 were used in this experiment. Five treatments namely, (i) control (crop grown at 80% of field capacity moisture) + recommended doses of N-P-K-S fertilizers (15.5-25.5-30.5-15.5 kg N-P-K-S ha^{-1} @ 0.20g, 0.80g, 0.40g and 0.20g/pot) (T_1), (ii) water stress (crop grown at 50% of field capacity moisture) + recommended doses of N-P-K and S (T_2), (iii) Water stress + 2 times higher of recommended doses of N-P-K-S (T_3), (iv) Water stress + 3 times higher of recommended doses of N-P-K-S (T_4) and (v) Water stress + 4 times of recommended doses of N-P-K-S (T_5) were imposed in the experiment. Pre-soaked six healthy seeds were sown in a pot and covered with soil by hand. After sowing of seeds light irrigation was given to ensure uniform germination of seeds. Seedlings were thinned out after one week of emergence keeping two healthy seedlings of uniform growth in each pot. Water stress treatments were imposed at 18 DAE, after completely 1st trifoliate development. One day before treatment imposition, 500 ml of water was applied to each pot to maintain similar soil moisture content in all the pots. Water stress condition was induced by withhelding water until wilting symptom was observed in plants. In

control treatment, water was applied to maintain moisture of 80% of field capacity when it was needed. Intercultural operations were done uniformly in each pot to ensure normal growth. The crop was harvested when the plants attained full maturity. The plant was cut at the soil surface level then threshing, cleaning and drying of seeds were done separately. The weight of seed and pod wall were recorded pot wise and adjusted at 12% moisture content. The data on different growth and yield related parameters were recorded from three plants of each replication. Seed weight was adjusted to 12% moisture content as follows:

$$\text{Seed yield at 12\% MC (g plant}^{-1}) = \frac{\text{100-Sample MC}}{\text{100-12\%}} \times \textit{fresh weight of seed}$$

Different growth parameters were calculated as follows:

$$\text{Crop Growth rate (CGR)} = \frac{W_2-W_1}{T^2 - T_1} \text{ g plant}^{-1} \text{ day}^{-1}$$

$$\text{Relative growth rate (RGR)} = \frac{\log_e W_2-\log_e W_1}{W_1(T_2-T_1)} \text{ g g}^{-1}\text{day}^{-1}$$

$$\text{Net assimilation rate (NAR)} = \frac{W_2 - W_1}{T_2-T_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1} \text{ g m}^{-2}\text{day}^{-1}$$

Where,
W_1 = Dry weight of plant at time T_1 (g)
W_2 = Dry weight of plant at time T_2 (g)
L_1 = Leaf area at time T_1 (m^2)
L_2 = Leaf area at time T_2 (m^2)

Reduction percentage of yield in water stress compared to control was calculated as follows Choukan *et al*. (2006).

$$\% \text{ Reduction} = \frac{Yp - Ys}{Yp} \times 100$$

Where, Y_p is the yield under non-stress condition and Y_s the yield under stress.

The data were analyzed by MSTAT-C statistical package program. The difference between the treatments means were compared by least significant difference (LSD) test following Gomez and Gomez (1983).

Results and Discussion

Morphological characteristics

Plant height: Water stress had an adverse effect on morphological characteristics of mungbean. The stress significantly reduced plant height at both recommended and increased doses of N-P-K-S fertilizers though the elevated doses of N-P-K-S fertilizers minimized the reduction at pre-flowering and maturity stages (Table 1). The tallest plants were recorded in the treatment T_4 for the variety Binamoog-5 (47.90 cm and 56.33 cm) and BUmug 4 (43.40 cm and 52.88 cm) both at pre-flowering maturity stage respectively with the elevated fertilizer doses. The treatment T_4 also showed the most effective to minimize effects the water stress on plant height in Binamoog-5 (6.9 % and 14.8 %) and in BU mug4 at (9.53% and 16.37%) at both stages followed by T_5. According to Waraich *et al*. (2011) high level of potassium is primarily responsible for the increase in plant height in the treatment with increasing doses of N-P-K-S under water stress conditions. The T_4 dose minimized the detrimental effects of water stress on plant height more efficiently than T_5 dose. The assumed reason behind the fact that the stressed plants were unable to uptake more nutrients due to water unavailability under water-deficit conditions.

Water stress reduced leaf area plant^{-1} with recommended and increased doses of N-P-K-S fertilizers application in Binamoog-5 and BU mug4. Increased doses of fertilizer was found effective to minimize detrimental effect of water stress on leaf area, where T_4 treatment was found as the most effective one. The maximum leaf area plant^{-1} was recorded in Binamoog-5 (789.1 cm^2 693.6 cm^2) and in BU mug4 (725.3 cm^2 and 610.7 cm^2) at pre-flowering and maturity respectively in the treatment with three-fold elevated dose of N-P-K-S (T_4) (Table 1). The reduction in leaf area plant^{-1} under water stress was the least in Binamoog-5 (7.8% and 5.5%) and BUmug 4 (8.9% and 10.1%) when T_4 treatment was applied, followed by T_5.

The root: shoot ratio noticeably increased under water deficit condition with recommended and increased doses of N-P-K-S fertilizer application. Although, all the increased doses of fertilizers application were found effective to minimize the negative impact of water stress on root and shoot development but the three-fold increased N-P-K-S (T_4) was found the most effective. At pre-flowering stage, the highest root: shoot ratio was recorded (0.128 and 0.119) in the T_4 treatment for the variety Binamoog-5 and BU mug4, respectively (Table 1). The highest increase in root and shoot ratio (17.19% and 15.97%) was recorded

Table 1. Morphological traits of mungbean plants as affected by elevated mineral nutrients grown under water stress

Treatments	Plant height (cm)				Leaf area plant^{-1}				Root:shoot ratio			
	PF-stage		Maturity-stage		PF-stage		Maturity-stage		PF-stage		Maturity-stage	
	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4
T_1	51.5	47.9	66.2	63.2	855.8	796.6	733.9	680.8	0.106	0.100	0.057	0.059
T_2	45.8 (11.1)	42.0 (12.5)	55.0 (16.8)	51.9 (17.8)	752.9 (12.0)	700.5 (12.1)	659.7 (10.1)	607.7 (10.7)	0.125 (15.2)	0.116 (13.8)	0.077 (25.9)	0.077 (23.4)
T_3	47.2 (8.4)	42.7 (10.9)	55.9 (15.5)	52.3 (17.2)	766.3 (10.5)	709.3 (10.9)	671.8 (8.5)	587.5 (13.7)	0.127 (16.5)	0.118 (15.2)	0.078 (26.9)	0.0780 (24.4)
T_4	47.9 (6.9)	43.4 (9.5)	56.3 (14.8)	52.8 (16.3)	789.1 (7.8)	725.3 (8.9)	693.6 (5.5)	610.7 (10.3)	0.128 (17.2)	0.119 (15.9)	0.079 (27.8)	0.080 (26.3)
T_5	47.7 (7.4)	43.1 (10.2)	56.0 (15.3)	52.7 (16.5)	786.8 (8.1)	723.8 (9.1)	688.6 (6.2)	602.6 (11.5)	0.127 (16.5)	0.118 (15.3)	0.079 (27.8)	0.080 (26.3)
CV (%)	6.9		8.3		7.8		9.4		4.1		7.6	
LSD $_{(0.05)}$	0.6		0.02		3.5		18.3		0.02		0.02	

*value in the parenthesis indicate the percent reduction compare to non-stress. Incase of root: shoot ratio, the values showed percent of increasement. T_1=No water stress+ recommended doses of N-P-K and S fertilizers (15.5-25.5-30.5-15.5 kg ha^{-1}), T_2=Water stress + recommended doses of N-P-K-S, T_3= Water stress + 2 times of recommended doses of N-P-K-S, T_4= Water stress + 3 times of recommended doses of N-P-K-S, T_5= Water stress + 4 times of recommended doses of N-P-K-S, PF-stage, preflowering stage; CV, coefficient of variation, LSD, least significant difference.

in Binamoog-5 and BUmug4 respectively under water stressed plants that treated with T_4 treatment. On the other hand, the highest root and shoot ratio was recorded (0.079 5 and 0.080) in both three-fold and four-fold increased doses of N-P-K-S fertilizers (T_4 and T_5) application and the increase of root and shoot ratio were (27.8% and 26.3%), in Binamoog-5 and BU mug4, respectively at maturity. Silva *et* al. (2011) reported that drought induced early closure of stomata, thus reduced transpiration rate and also limited the transport of nutrients from the root to the shoot. Thus drought stress reduces availability and transport of nutrients to plant tissues and ultimately the plant growth. Although there have been multiple studies on the effect of nutrient delivery on plant growth, it is generally accepted that during drought, increasing fertilizer availability will encourage plant growth (Ahanger *et al.* 2016).

Partition of dry matter : Increased doses of N-P-K-S fertilizers considerably minimized the detrimental effects of water stress on root dry weight both at pre-flowering and maturity stages in Binamoog-5 and BU mug4 (Table 2). Among the elevated doses of fertilizer, the three-fold increased of N-P-K-S (T_4) at pre-flowering stage were found most effective to minimize the water stress effects on root dry weight but the three and four-fold of N-P-K-S (T_4 and T_5) was effective at maturity. Among the increased doses, the highest root dry weight (0.74 g and 0.62 g) was recorded in the T_4 treatment at pre-flowering stage whereas, at maturity stage the highest root dry weight (1.06 g and 0.92) was observed in the both T_4 and T_5 treatment for Binamoog-5 and BU mug4, respectively. At pre-flowering stage, the highest increase in root dry weight (12.16% and 8.06%) was found T_4 treatment but at maturity, the maximum increase of root dry weight (9.43% and 7.60%) was found when both T_4 and T_5 treatments were applied. Water stress significantly reduced leaf dry matter irrespective of recommended and increased doses of N-P-K-S fertilizers in Binamoog-5 and BU mug4. Increased doses fertilizers over recommended dose significantly minimized the detrimental effects of water stress on leaf dry weight plant^{-1} both at pre-flowering and maturity stages (Table 2). Among the increased doses, the T_4 treatment was found more effective to minimize the water stress effects on leaf dry weight plant^{-1}. The highest leaf dry weight plant^{-1} was recorded in Binamoog-5 (3.32 g and 3.56 g) and in BU mug4 (2.58 g and 3.18 g) at both

Table 2. Dry matter partitioning of mungbean plants as affected by elevated mineral nutrients grown under water stress

Treatments	Root dry weight (g plant^{-1})				Leaf dry weight (g plant^{-1})				Stem dry weight (g plant^{-1})				Total dry matter (g plant^{-1})			
	PF-stage		Maturity-stage		PF-stage		Maturity-stage		PF-stage		Maturity-stage		PF-stage		Maturity-stage	
	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4
T_1	0.65	0.57	0.96	0.85	3.61	2.86	4.03	3.62	3.14	2.89	3.35	2.85	8.28	7.03	28.02	23.61
T_2	0.69 (5.80)	0.59 (3.39)	1.02 (5.88)	0.89 (4.49)	3.13 (13.30)	2.37 (17.13)	3.38 (16.12)	3.00 (17.13)	2.75 (12.42)	2.49 (13.84)	3.11 (7.16)	2.60 (8.77)	7.40 (10.63)	6.10 (13.22)	17.25 (38.34)	14.20 (39.86)
T_3	0.71 (8.45)	0.60 (5.00)	1.04 (7.69)	0.91 (6.59)	3.22 (10.80)	2.50 (12.58)	3.47 (13.90)	3.11 (14.09)	2.93 (6.69)	2.65 (8.30)	3.16 (5.67)	2.66 (6.67)	7.71 (6.88)	6.42 (8.68)	17.93 (36.01)	14.68 (37.82)
T_4	0.74 (12.16)	0.62 (8.06)	1.06 (9.43)	0.92 (7.60)	3.32 (8.03)	2.58 (9.79)	3.56 (11.66)	3.18 (12.15)	3.04 (3.18)	2.75 (4.84)	3.22 (3.88)	2.71 (4.91)	7.96 (3.86)	6.64 (5.55)	18.54 (33.83)	15.09 (36.09)
T_5	0.71 (8.45)	0.61 (6.56)	1.06 (9.43)	0.92 (7.60)	3.26 (9.70)	2.54 (11.18)	3.47 (13.90)	3.10 (14.36)	3.02 (3.82)	2.62 (9.34)	3.17 (5.37)	2.65 (7.02)	7.86 (5.07)	6.44 (8.39)	18.12 (35.33)	14.78 (37.40)
CV (%)	7.00		6.92		8.62		6.25		9.26		7.51		8.17		7.33	
LSD $_{(0.05)}$	0.02		0.05		0.02		0.02		0.08		0.02		0.02		1.08	

*value in the parenthesis indicate the percent reduction compare to non-stress. Incase of root dry weight, the values showed percent of increasement.T_1=No water stress+ recommended doses of N-P-K and S fertilizers (15.5-25.5-30.5-15.5 kg ha^{-1}), T_2=Water stress + recommended doses of N-P-K-S T_3= Water stress + 2 times of recommended doses of N-P-K-S, T_4= Water stress + 3 times of recommended doses of N-P-K-S, T_5= Water stress + 4 times of recommended doses of N-P-K-S, PF-stage, preflowering stage; CV, coefficient of variation; LSD, least significant difference.

pre-flowering and maturity in the T_4 treatment. The least reductions of leaf dry weight plant^{-1} found in Binamoog-5 (8.03% and 11.66%) and BU mug4 (9.79% and 12.15%) when T_4 was applied followed by T_5. The less reduction under water stress treatment with increased N-P-K-S fertilizer application than that with recommended fertilizer was probably due to less defoliation that led to less reduction in leaf dry weight. Increased doses of N-P-K-S fertilizers over recommended doses significantly minimized the negative impact of water stress on stem dry matter plant^{-1} at both at pre-flowering and maturity stage, (Table 2). Among the increased doses, the T_4 treatment was found the most effective to minimize the detrimental effects of water stress on stem dry weight at both stages. The highest stem dry weight was recorded in Binamoog-5 (3.04 g and 2.75 g) and in BU mug4 (2.75 g and 2.71 g) with the treatment T_4 at both pre-flowering and maturity stages. The least reduction of stem dry weight was noticed with the elevated fertilizer treatment T_4 in Binamoog-5 (3.18% and 3.88%), and in BU mug 4 (4.84% and 4.91%) at both pre-flowering and maturity stages. Water stress significantly affected the total dry matter (TDM) in mungbean. In water stressed plants, the TDM was significantly reduced but that increased with higher doses of N-P-K-S irrespective of the varieties both at pre-flowering and maturity stages. All the increased doses of fertilizer significantly minimized the detrimental effects of water stress on total dry matter weight over recommended dose both at pre-flowering and maturity stages (Table 2). The highest total dry matter plant^{-1}

was found in Binamoog-5 (7.96 g and 18.54 g) and in BU mug4 (6.64 g and 15.09 g) at both pre-flowering and maturity with the elevated fertilizer dose of T_4. Although the reduction in total dry matter weight plant^{-1} was less when the water stressed plants were treated with T_4 treatment, and the least reductions in Binamoog-5 (3.86% and 33.83%) and in BU mug4 (5.55% and 36.09%) at both pre-flowering and maturity stages. In an experiment, Raza *et al.* (2014) found that after 15 days of imposition of the stress, the number of leaves, shoot length, shoot fresh weight and dry weight, seedling fresh weight, and photosynthetic pigments all significantly changed under stress. According to Zayed and Zeid (1997) the absence of nutrient accumulation caused a considerable reduction in mungbean plants' growth, chlorophyll content, and mineral uptake when they were under water stress.

Growth analysis traits: Water stress had an adverse effect on growth related traits such as plant growth rate, relative growth rate and net assimilation rate (Figure 1). Initially, all the growth parameters were more in both the varieties irrespective of control and water deficit conditions. The reduction percent of all studied growth related traits in both the varieties were high in recommended dose of fertilizer but it was drecreased with increased doses of mineral nutrients. The maximum reduction was observed with three fold increased dose (Figure 1). Plant growth rate (PGR) significantly reduced under water stress conditions irrespective of recommended and increased doses of N-P-K-S fertilizer. The highest PGR was recorded in Binamoog-5 (0.434 g plant^{-1} day^{-1}) and in BU mug4 (0.327 g plant^{-1} day^{-1}) at pod initiation stage for the treatment with three-fold increased dose of N-P-K-S (T_4) fertilizer. The lowest reduction of PGR was recorded in Binamoog-5 (17.96%) and in BU mug4 (20.82%) at pod initiation stage in T_4 treatment among the increased doses of fertilizer application (Figure 1A). It is clear that under water stress all the increased doses of N-P-K-S fertilizer application maintained a good PGR over the recommended dose at pod initiation stage. This is an indication of improvement of drought tolerance level in mungbean plants under water stress through elevated nutrient application.

The relative growth rate (RGR) was higher at early growth stages and thereafter showed decreasing trend with the advancement of plant age in recommended and increased

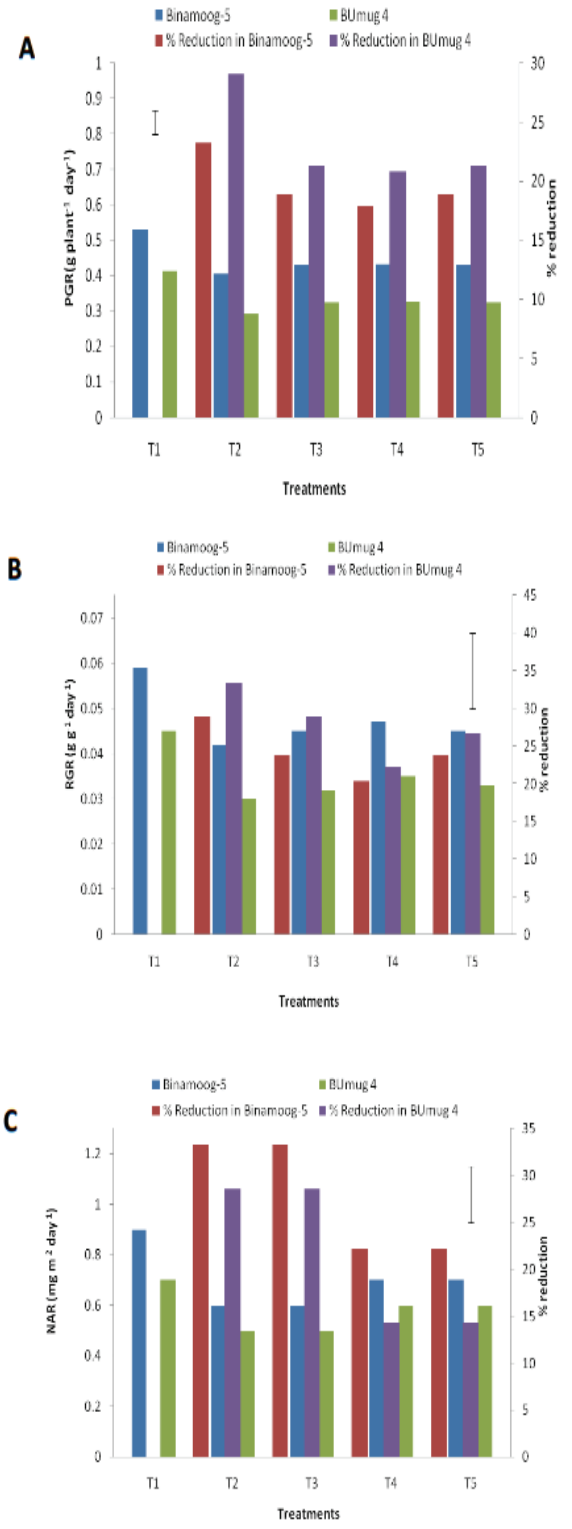


Figure 1. Growth parameters of mungbean plants as affected by elevated mineral nutrients under water stress.

doses of N-P-K-S fertilizer irrespective of Binamoog-5 and BU mug4. The three-fold increased doses of N-P-K-S (T_4) fertilizer application minimized the detrimental effects effectively than other increased doses of fertilizer. The highest RGR in Binamoog-5(0.047 $gg^{-1}day^{-1}$) and in BU mug4 (0.035 g g^{-1} day^{-1}) was recorded in the treatment T_4 (Figure 1B). The lowest reduction of RGR was recorded in Binamoog-5 (20.34%) and in BU mug4 (22.22%) at pod ignition stage among the increased fertilizer doses. The decrease in RGR with time might be due to decrease in net assimilation rate which caused by leaf senescence under water stress conditions (Moayedi *et al*. 2011).

The net assimilation rate (NAR) is the increase in dry weight per unit time per unit leaf area present (Milthorpe and Moorbby 1979). The NAR was higher at early growth stages and thereafter showed decreasing trend with the advancement of plant age and maintained up to maturity. The highest NAR was recorded in Binamoog-5 (0.7 mg m^{-2} day^{-1}) and in BU mug4 (0.6 mg m^{-2} day^{-1}) in the treatment with T_4 and T_5 among the increased doses of N-P-K and S application (Figure 1C). The lowest reduction in NAR was recorded in Binamoog-5 (24.29%) and in BU mug4 (35.71%) in the T_4 treatment. The increased doses of N-P-K-S could not improve the net assimilation rate of $plant^{-1}$ in water stressed mungbean plants due to leaf rolling which consequently decreased the photosynthetic leaf area as well as the rate of photosynthesis. Siddiqui *et al.* (2023) conducted an experiment with six popular mugbean varieties under both water stress and non-stress condition. They found that all the growth parameters namely crop growth rate, relative growth rate and net assimilation rate drecreased greatly under stressed condition compared to the non-stress at both pre-flowering and maturity stages.

Yield and yield contributing traits: Water stress significantly reduced the number of pods $plant^{-1}$ in the mungbean varieties, Binamoog-5 and BU mug4 irrespective the doses of N-P-K-S. Two-fold (T_3), three-fold (T_4) and four-fold (T_5) increased doses of N-P-K-S fertilizer over recommended dose significantly minimized the detrimental effects of water stress on pods $plant^{-1}$ (Table 3). Among the increased doses fertilizers, the T_4 was found the most effective to minimize the water stress effects on pods $plant^{-1}$. The highest number of pods $plant^{-1}$ was recorded in Binamoog-5 (15.33) and in BU mug4 (13.33) in the treatment T_4. The reduction in pods $plant^{-1}$ was less in water stressed plants treated with increased dose of fertilizer. However, the least reduction was found in Binamoog-5 (39.47%) and in BU mug4 (442.04%) in T_4 treatment.

Table 3. Effect of elevated NPKS on yield and yield components of mungbean plants under water stress

Treatments	Pods $plant^{-1}$		Seed pod^{-1}		Pod length (cm)		Hundred seed weight		Seed yield $plant^{-1}$	
	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4	Bina moog-5	BU mug 4
T_1	25.3	23.0	10.4	9.7	8.27	7.81	4.77	4.44	11.18	9.57
T_2	12.0 (52.6)	12.0 (47.8)	7.9 (23.6)	7.2 (25.9)	7.73 (6.53)	7.21 (7.68)	4.58 (3.98)	4.21 (5.18)	4.51 (59.66)	3.83 (59.98)
T_3	13.3 (47.4)	12.0 (47.8)	8.1 (21.6)	7.3 (24.9)	7.89 (4.59)	7.32 (6.27)	4.65 (2.52)	4.29 (3.38)	4.76 (57.42)	3.90 (59.25)
T_4	15.3 (39.5)	13.3 (42.0)	8.2 (20.8)	7.4 (23.90	7.95 (3.87)	7.40 (5.25)	4.65 (2.52)	4.29 (3.38)	4.95 (55.72)	3.95 (58.73)
T_5	14.3 (43.2)	12.7 (44.9)	8.2 (21.1)	7.4 (24.4)	7.91 (4.35)	7.37 (5.63)	4.61 (3.35)	4.25 (4.28)	4.89 (56.26)	3.90 (59.25)
CV (%)	9.1		8.2		6.24		6.22		9.55	
$LSD_{(0.05)}$	0.7		0.1		0.02		0.02		0.25	

*value in the parenthesis indicate the percent reduction compare to non-stress. T_1=No water stress+ recommended doses of N-P-K and S fertilizers (15.5-25.5-30.5-15.5 kg ha^{-1}), T_2=Water stress + recommended doses of N-P-K-S T_3= Water stress + 2 times of recommended doses of N-P-K-S, T_4= Water stress + 3 times of recommended doses of N-P-K-S, T_5= Water stress + 4 times of recommended doses of N-P-K-S; PF-stage, preflowering stage; CV, coefficient of variation, LSD, least significant difference.

Three-fold increased doses of N-P-K-S (T_4) over recommended dose significantly minimized the detrimental effects of water stress on pod length at maturity among more than other doses of fertilizers (Table 3). The longest pod was recorded in Binamoog-5 (7.95 cm) and in BU mug4 (7.40 cm) in the treatment T_4. The reduction in pod length was less in water stressed plants treated with increased doses of fertilizer where, the least reduction was observed in Binamoog-5 (3.87%) and in BU mug4 (5.25%) with T_4 treatment.

Water stress significantly reduced number of seeds pod^{-1} in the mungbean irrespective of recommended and increased doses of N-P-K-S fertilizer application. Increased doses of the fertilizers over recommended doses significantly minimized the detrimental effects of water stress on number of seeds pod^{-1} (Table 3). The highest number of seeds pod^{-1} was recorded in Binamoog-5 (8.22) and in BU mug 4 (7.37) in the treatment with three-fold increased doses of N-P-K-S fertilizer (T_4). The reduction in number of seeds pod^{-1} was less in water stressed plants treated with elevated fertilizer doses and the least reduction was observed in Binamoog-5 (20.81%) and in BUmug 4 (23.94%) in T_4 treatment.

Water stress significantly reduced the 100-seed weight in mungbean variety Binamoog-5 and BU mug4. Increased doses of N-P-K-S fertilizers over recommended doses significantly minimized the detrimental effects of water stress on 100-seed weight. The highest 100-seed weight was recorded in Binamoog-5 (4.65 g) and in BU mug4 (4.29 g) with the three-fold increased doses of N-P-K-S fertilizer (T_4) treatment (Table 3). The least reduction in 100-seed weight was recorded in Binamoog-5 (2.52%) and in BUmug4 (3.38%) in T_3 and T_4 treatments respectively.

Seed yield plant^{-1} significantly decreased irrespective of recommended and increased doses of N-P-K-S fertilizer application in Binamoog-5 and BUmug4 under water stress. Increased doses of fertilizer over recommended dose significantly reduced the detrimental effects of water stress on yield contributing characters resulting in less reduction in seed yield plant^{-1}. Three-fold N-P-K-S increased doses of fertilizer (T3) minimized the detrimental effects on stress plants more effectively among all of the increased doses of fertilizers. In water stressed plants, the highest yield plant^{-1} was recorded in Binamoog-5 (4.95 g) and in BU mug4 (3.95 g) in T_4 treatment (Table 3). The lowest reduction in seed yield plant^{-1} was found in Binamoog-5 (55.72%) and in BU mug4 (58.73%) in the treatment T_4 followed by T_5 tratment. Ranawake *et al.* (2011) found a significant difference between control plants and water stressed plants of Mungbean, where the average yield was around 4.08g/plant in control, while it was 1.5g/plant, 0.75g/plant and 2.9g/plant in 3 WAP, 6 WAP and 8 WAP drought stressed plants respectively. The findings of the study also comply with the results of Amanullah *et al.* (2022) who revealed that crop under no water stress had better growth by producing taller plants with a more number of leaves, nodules, and pods plant^{-1}, seeds pod^{-1}, heavy 1000-grain weight, higher biological and grain yields than water stress condition. The study also confirmed that the combination of the highest rate of different nutrients improved the vegetative growth and development, and significantly increased yield and yield components under both water stress and no stress conditions.

Conclusion

Mungbean growth and yield were affected by water stress, and elevated doses of fertilizer (N-P-K-S) reduced the harmful effects of water stress. Three-fold dose of N-P-K-S (@ 46.5-76.5-91.5-46.5 kg ha^{-1}) over recommended dose was the most efficient to alleviate the adverse impacts of water stress on growth and yield of mungbean.

Acknowledgement

We acknowledge greatly the Ministry of Science and Technology (MoST) for supporting financially in conducting the present study.

References

Abbasi AR, Sarvestani R, Mohammadi B and Baghery A. 2014. Drought stress-induced changes at physiological and biochemical levels in some common vetch, *Vicia sativa* L. genotypes. Journal of Agricultural Science and Technology, *16*: 505-516.

Ahanger MA, Morad-Talab N, Abd-Allah EF, Ahmad P and Hajiboland R. 2016. Plant growth under drought stress: significance of mineral nutrients. Water Stress and Crop Plants: a Sustainable Approach, *2*: 649-668.

Ali MA, Jabran K, Awan SI, Abbas A, Zulkiffal M, Acet T and Rehman A. 2011. Morpho-Physiological diversity and its implications for improving drought tolerance in gram sorghum at different growth stages. Australian Journal of Crop Science, *5*: 311-320.

Amanullah MY, Khalid S, Elshikh MS, Akram HM, Imran and Ali A. 2022. Phenology, growth, productivity, and profitability of mungbean as affected by potassium and organic matter under water stress vs. no water stress conditions. Journal of Plant Nutrition, *45*: 629-650.DOI 10.1080/01904167.2021.1936025.

Anjum SA, Xie X, Wang LC, Saleem MF, Man C and Lei W. 2011. Morphological, physiological and biochemical responses of plants to drought stress. African Journal of Agricultural Research, *6*: 2026-2032.

Azadi E, Rafiee M and Nasrollahi H. 2013. The effect of different nitrogen levels on seed yield and morphological characteristic of mungbean in the climate condition of Khorramabad. Annals of Biological Research, *4*: 51-55.

Baroowa B and Gogoi N. 2015. Changes in plant water status, biochemical attributes and seed quality of black gram and green gram genotypes under drought. International Letters of Natural Sciences, *42*: 10-12.

BBS 2022. Bangladesh Bureau of Statistics. Yearbook of Statistics of Bangladesh. Statistics Division. Ministry of Planning, Government of the Peoples Republic of Bangladesh, Dhaka. http://www.bbs.gov.bd.

D'Oria A, Courbet G, Billiot B, Jing L, Pluchon S, Arkoun M, Maillard A, Roux CPL, Trouverie J, Etienne P and Diquélou S. 2022. Drought specifically downregulates mineral nutrition: Plant ionomic content and associated gene expression. Plant Direct, *6*: e402.

Brammer H. 1971. Soil resources and soil survey project in Bangladesh. Agricultural Statistics of Pakistan, *6*: 14-18.

Choukan R, Taherkhani T, Ghannadha MR and Khodarahmi M. 2006. Evaluation of drought tolerance in grain maizeinbred lines using drought tolerance indices. Iranian Journal of Agricultural Science, *8*: 79-89.

da Silva EC, Nogueira RJMC, da Silva MA and de Albuquerque MB. 2011. Drought stress and plant nutrition. Plant Stress, *5*: 32-41.

FRG (Fertilizer Recommendation Guide). 2012. Bangladesh Agricultural Research Council (BARC). Farmgate, Dhaka 1215, 274p.http://www.barc.gov.bd.

Giri A, Heckathorn S, Mishra S and Krause C. 2017. Heat stress decreases levels of nutrient-uptake and-assimilation proteins in tomato roots. Plants, *6*: 6.

Gomez KA and Gomez AA. 1983. Statistical Procedure for Agricultural Research. John Wiley and Sons. New York, Pp. 20-215.

Islam KN, Khan MMH, Islam MM, Uddin MM and Latif MA. 2020. Performance of different cultivars of mungbean in coastal region of Bangladesh. SAARC Journal of Agriculture, *18*: 161-172. DOI 10.3329/sja.v18i1.48390.

Khan MIR, Nazir F, Maheshwari C, Chopra P, Chhillar H and Sreenivasulu, N. 2023. Mineral nutrients in plants under changing environments: A road to future food and nutrition security. The Plant Genome, e20362.

Kirkby EA, Nikolic M, White PJ and Xu G. 2023. Mineral nutrition, yield, and source–sink relationships. In: Marschner's mineral nutrition of plants, Pp. 131-200.

Mahajan G, Wenham K and Chauhan BS. 2023. Mungbean (*Vigna radiata* L) Growth and yield response in relation to water stress and elevated day/night temperature conditions. Agronomy, *13*: 25-46.

Manivannan P, Jaleel CA, Sankar B, Kishorekumar A, Somasundaram R, Lakshmanan GA and Panneerselvam R. 2007. Growth, biochemical modifications and proline metabolism in *Helianthus annuus* L. as induced by drought stress. Colloids and Surfaces B: Biointerfaces, *59*: 141-149.

Mehta N, Rao P and Sain R. 2021. A review on metabolites and pharmaceutical potential of food legume crop mung bean (*Vignaradiata* L. Wilczek). Biotechnologia (Pozn), *102*: 425–435. Published online 2021 Dec 22. doi: 10.5114/bta.2021.111107

Milthorpe FL and Moorbby A. 1979. An Introduction to Crop Physiology. Second edition, Cambridge University Press, P. 75.

Moayedi AA, Boyce AN, Barakbah SS and Kafi M. 2011. Water deficit-induced changes on growth parameters and radiation use efficiency of promising durum wheat genotypes. Journal of Food, Agriculture & Environment, *9*: 563-565.

Ranawake AL, Dahanayaka N, Amarasingha UGS, Rodrigo WDRJ and Rodrigo UTD. 2011. Effect of water stress on growth and yield of mungbean, *Vigna radiate* L.Tropical Agricultural Research and Extension, *14*: 2011.

Saleem S, Mushtaq NU, Rasool A, Shah WH, Tahir I and Rehman RU. 2023. Plant nutrition and soil fertility: physiological and molecular avenues for crop improvement. Sustainable Plant Nutrition, Pp. 23-49.

Siddiqui S A, Mahmud A, Khaliq QA, Haque MM, Solaiman ARM and Karim MA. 2023. Growth and yield variations in mungbean varieties under water stress. Ecology Journal, *5*: 37-47.

Silva EC, Nogueira RJMC, Silva MA and Albuquerque M. 2011. Drought stress and plant nutrition. Plant Stress, *5*: 32-41.

Waraich EA, Ahmad R and Ashraf MY. 2011. Role of mineral nutrition in alleviation of drought stress in plants. Australian Journal of Crop Science, *5*: 764-777.

Zayed MA and Zeid IM. 1997. Effect of water and salt stresses on growth, chlorophyll, mineral ions and organic solutes contents, and enzymes activity in mungbean seedlings. Biologia Plantarum, *40*: 351-356.