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Effect of Nitrogen and Potassium on the Root Growth, Nutrient Content and Yield of Mungbean (*Vigna radiata* L. Wilczek) under Waterlogged Condition

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Abstract

An experiment was conducted with mungbean genotype IPSA-13 in the field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh during September, 2012 to November, 2012 to study the root growth, nutrient concentration and seed yield of mungbean as influenced by N and K under waterlogged conditions. Nutrient supply in the soil had significant impact on better recovery in root development of 4-day waterlogged plants. Development of adventitious roots was one of the adaptive responses of IPSA-13 mungbean genotype. Root length was decreased due to the anaerobic condition. Plants waterlogged for 4-days allocated more dry matter in adventitious root development and hence root volume was higher in waterlogged plants. Root volume in flooded plants increased due to the development of adventitious roots. Root dry weight increased with combined application of N and K fertilizers. Flooded plants treated with 14 kg N ha^{-1} + 25 kg K ha^{-1} produced the highest TDM and seed yield, though the yield was statistically similar to that obtained when the levels of N and K were applied separately, as well as with that of 1% urea + 25 kg K ha^{-1}.

Keywords: Nitrogen and potassium, root growth, nutrient content, soil moisture, mungbean

1. Introduction

Mineral nutrition in waterlogged soil may limit the plant growth due to the alterations of nutrient uptake of plants. Nutrient deficiency is the major cause of poor plant growth in waterlogged soil (Steffens *et al.*, 2005). Waterlogging was reported to have caused a significant decrease in nitrogen content in plants due to reduced root activity and yellowing of leaves (Rao *et al.*, 2002). Crops generally fail to adapt in wet soil conditions due to smaller quantity of dry matter accumulation in shoot and root (Drew, 1991; Huang *et al.*, 1995). Islam (2005) observed that during waterlogging in most of mungbean genotypes adventitious roots were grown quickly during post-flooding period. From adventitious root systems, an important supply of oxygen to roots of many plants is achieved (Glinski and Stepiewski, 1985; Kozlowski, 1984).

Mungbean (*Vigna radiata* L. Wilczek) is one of the most popular food legumes widely cultivated in the tropical regions of the world. Excess moisture or soil waterlogging have been found to cause depression of plant characters and yield of mungbean (Hamid *et al.*, 1991; Miah *et al.*, 1991). On the other hand, nutrient supply and availability in the soil plays a significant impact on waterlogging tolerance of plants (Huang, 2000; Romheld and Kirkby, 2010). Waterlogging inhibits root respiration due to insufficient supply of oxygen (Das *et al.*, 2009). Exogenous application of N in flooded bushbean, cowpea and sweet corn (Li *et al.*, 2012) and K in upland cotton (Ashraf *et al.*, 2011) could effectively ameliorate the adverse effects of waterlogging on plants. Habibzadeh *et al.* (2013) reported that the effects of foliar applications of urea, calcium nitrate and potassium nitrate can alleviate the growth-inhibiting effects of waterlogging of canola plants.

Application of nitrogen at the end of a waterlogging period can be an advantage if nitrogen applied at or shortly after seeding has been lost by leaching or denitrification as reported by McFarlane (2012). From basic physiological investigations, applied nitrate may enter anaerobically in damaged roots by passive means and be translocated to the shoot as reported by Trought and Drew (1981). Waterlogging reduces soil aeration and the amount of oxygen available to plant roots. Under such conditions, K concentration in the soil solution has to be increased or in more practical terms more potash fertilizer has to be applied where there is a risk of oxygen shortage (PPIC, 1989). K supplement under waterlogging not only increases plant growth, photosynthetic pigments and photosynthetic capacity, but also improves plant nutrient uptake and accumulation (Ashraf *et al.*, 2011). Therefore, combined use of fertilizers can improve the root and shoot growth of mungbean when the plants were affected by waterlogging during their growing periods.

Waterlogging is a problem in growing mungbean in the tropics and sub-tropics. Although a good number of reports on the excess moisture tolerance of many upland crops such as wheat (Hossain *et al.*, 2011), barley and oats (Setter and Waters, 2003) and maize (Zaidi *et al*., 2007) are available elsewhere but such studies on mungbean are limited. It is presumed that application of excess N and K in combination will protect more effectively the mungbean plants from waterlogging damage than they show separately. Little information is available on the development and recovery of roots of mungbean grown under waterlogged condition. This experiment was therefore, conducted to observe the root growth, nutrient uptake potentials and yield performance of waterlogged mungbean receiving variable doses of applied N and K fertilizers.

2. Materials and Methods

2.1. Experimental site and soil type

The study was conducted at the Agronomy Research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur-1706, Bangladesh during September, 2012 to November, 2012. The soil of the experimental plots was silty clay of shallow Red Brown Terrace soil belongs to ‘Salna’ soil series under Madhupur Tract (AEZ 28).

2.2. Experimental design, treatments and layout

The experiment was carried out with mungbean genotype IPSA-13. The experiment was set up in a randomized complete block design with four replications. Five treatments were: (i) T_1= Control (4-day waterlogged but not fertilized after termination of waterlogging) (ii) T_2= 4-day waterlogged and received 14 kg N ha^{-1} broadcasted after termination of waterlogging (iii) T_3= 4-day waterlogged and received 25 kg K ha^{-1} broadcasted after termination of waterlogging (iv) T_4= 4-day waterlogged and received 14 kg N ha^{-1} + 25 kg K ha^{-1} broadcasted after termination of waterlogging (v) T_5 = 4-day waterlogged + foliar spray with 1% urea solution after termination of waterlogging + 25 kg K ha^{-1} broadcasted after termination of waterlogging.

The size of each plot was (2m x 2m) = 4 m^2. Seeds of mungbean were sown maintaining a spacing of 30 cm x 10 cm. At the border of each plot, one additional row of mungbean was grown to avoid border effect. When the seedlings became 24 days old, waterlogging with 3-5 cm of standing water was maintained continuously above the soil surface for 4 days (96 hours) during 24-27 days after emergence and thereafter standing water was removed. Fertilizer treatments were applied as broadcast in the form of urea and muriate of potash and 1% urea solution was sprayed on the foliage of the plants following the termination of waterlogging. Drain in between two waterlogged plots was 1.5 m so that water could not soak to the neighboring plots.

2.3. Land preparation, fertilization and management

The experimental land was ploughed properly and at the time of first ploughing, cowdung at 10 t ha^{-1} was applied. A blanket dose of fertilizers @ 40-25-35 kg ha^{-1} of N-P-K was applied and incorporated into the soil at the time of final land preparation. Additional application of N and K was applied in waterlogged plants after removal of water from the experimental plots according to the treatment variations (T_2-T_5) cited above. Seeds of uniform size and shape were sorted from their stock and treated with Vitavex 200 @ 2 g per kg seed. The seeds were soaked in water for 4 hours before sowing and imbibed seeds were selected for sowing. Most seedlings emerged within 3 days after sowing.

Seedlings were thinned out after one week of emergence keeping healthy seedlings of uniform growth in each plot. During growing period the average maximum and minimum temperatures ranged between 31.16^{o}C and 22.23^{o}C, respectively**.** The total rainfall of the area during the experimentation was 229.30 mm**.** Admire @ 2.0 ml litre^{-1} water was sprayed to protect the plants from insects. Other management practices were done adequately to maintain normal growth of seedlings.

2.4. Data collection

Five plants were harvested from 4-day waterlogged control and waterlogged fertilized plots for data collection. Data were collected after termination of 4-day waterlogging beginning from 28th days after emergence and thereafter each 10 days interval. At each sampling required data viz. root length, root volume, root dry weight, total dry matter, days to first 50% flowering and maturity was recorded. The plants harvested at maturity and yield parameters were recorded.

Collection of roots: Five plants were dug out gently from each experimental plot with spade digging enough depth of soil, so that the main tap root and all the lateral roots could be uprooted successfully. The sample plants were kept in poly bags full of water and kept for about 12 hours. The roots were washed thoroughly using 10 mesh sieves so that no root was left and the roots were separated easily.

Root length: Roots of each plant were cut down from the base of the plant and the roots were placed on the square board (1sq. cm sizes graph paper) to determine the total number of intercepts. The total number of intercepts of the roots with the arms of the squares was counted and total root length was calculated.

Root volume: Root volume of mungbean was measured following the law of Archimedes. Root of a single plant was placed in a water-filled measuring cylinder. Root volume replaced the similar volume of water. The difference between the water level in the measuring cylinder before and after placing the roots was measured as the volume of roots in cm^3.

Chemical analysis: Nitrogen content in plant was determined following Micro Kjeldahl method by sulphuric acid digestion method. Phosphorus content was determined digesting plant samples with diacid mixture (nitric: perchloric acid = 3:1) and colour was developed by vanadium molibdate yellow colour method. Potassium content was determined by atomic absorption spectrophotometer digesting plant sample with diacid mixture. The oven dried leaf, plant and seeds were finely ground and total concentration was determined by the above methods.

Weather data: Weather data were collected from the meteorological station of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur.

2.5. Statistical analysis

The data on different parameters were subjected to statistical analysis. Microsoft EXCEL and MSTAT-C software programs were used wherever appropriate to perform statistical analysis. All recorded data were analyzed using analysis of variance (ANOVA) and means were compared using Least Significant Difference (LSD) test according to Gomez and Gomez (1984).

3. Results and Discussion

3.1. Duration of flowering and maturity

Days to 50% flowering and maturity are shown in Table 1. Days to 50% flowering in control treatment (T_1) required 39 days after emergence and did not differ significantly among the waterlogged fertilized treatments (T_2-T_5). The earliest flowering was observed in the treatment T_3 (4-day waterlogged and received 25 kg K ha^{-1}) (33 DAE). The treatment T_4 (4-day waterlogged plants and received 14 kg N ha^{-1} + 25 kg K ha^{-1}) (35 DAE) and the treatment T_5 (1% urea foliar spray + 25 kg K ha^{-1}) (35 DAE) were statistically similar. Soil waterlogging delayed flowering but application of N and K fertilizers after termination of waterlogging probably enhanced early flowering by 4 to 6 days compared to that of control. Generally, N in plants delay flowering and K accelerate maturity and ripening. Control treatment (69 DAE) and waterlogged fertilized plants (66 to 68 DAE) differed in days to maturity by 4-5 days. Days to maturity among the waterlogged plants with or without fertilization did not differ significantly.

3.2. Root formation under waterlogging

3.2.1. Root length

Since tap roots were highly affected by waterlogging, roots of 4-day waterlogged plants with single or combine application of variable doses of N and K fertilizers became shortened as observed at different growth stages of mungbean (Figure 1). Similar result was also found by Davies *et al.* (1999) in waterlogged-susceptible lupin. Root length was higher after termination of waterlogging at 0 days after termination of flooding (DTF) and ranged from 11.25 cm to 13.50 cm, decreased during the recovery period (10 DTF) ranged from 10.30 cm to 11.50 cm, and increased thereafter (20 DTF) ranged from 11.00 cm to 13.25 cm. At maturity, root length of waterlogged-stressed plants (T_2-T_5) was statistically identical with or without fertilization (T_1).

Table 1. Days to 50% flowering and maturity of mungbean as influenced by N and K application after removal of waterlogging

Treatment	Days to 50% flowering	Days to maturity
T_1 (Soil waterlogging as control)	39	69
T_2 (Waterlogging + 14 kg N)	35	68
T_3 (Waterlogging + 25 kg K)	33	67
T_4 (Waterlogging + 14 kg N + 25 kg K)	35	67
T_5 (Waterlogging + 1% urea spray + 25 kg K)	35	66
$LSD_{0.05}$	2.55	2.362
CV (%)	1.394	2.34

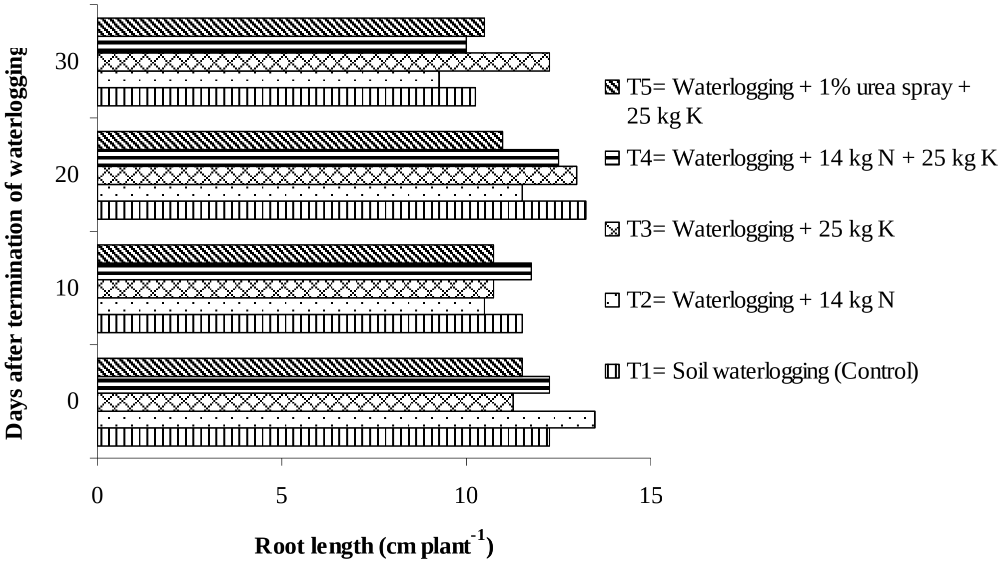

Figure 1. Root length plant^{-1}of mungbean as influenced by N and K application after removal of waterlogging.

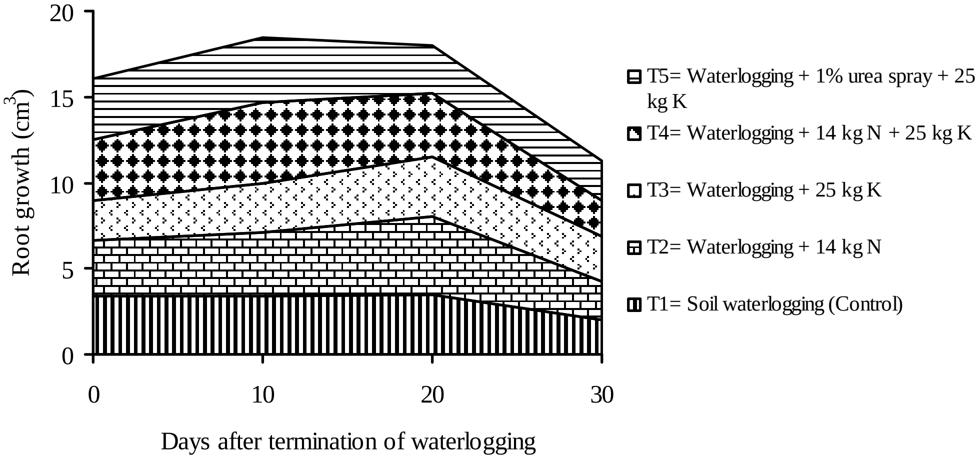

Figure 2. Root volume plant^{-1} of mungbean as influenced by N and K application after removal of waterlogging.

3.2.2. Root volume

The root volume (cm^3) of mungbean genotype IPSA-13 did not show any significant change before fertilization (0 DTF) among the waterlogged plants (Figure 2). Root volume in waterlogged plants increased during 10 days recovery period and continued to increase upto 20 DTF and again decreased at maturity (30 DTF). The T_4 treatment (4-day waterlogged and received 14 kg N ha^{-1} + 25 kg K ha^{-1}) produced statistically higher volume of roots than other treatments which were significantly different form other waterlogged treatments. The increased root volume in waterlogged mungbean might be due to the development of adventitious roots having aerenchyma cells, one of the adaptive mechanisms of mungbean plant. In waterlogged-tolerant plants, the formation of aerenchyma and adventitious roots was reported as an indicator of the presence of adaptive mechanism (Kawase, 1981). At maturity, root volume of non-fertilized and fertilized waterlogged plants was statistically non-significant.

3.2.3. Root dry weight

Root dry weight of waterlogged plants increased gradually from termination of waterlogging upto pod filling stage and decreased at maturity (Figure 4). The cause of decrease in root dry weight at the pod development stage was presumably due to senescence or decaying of roots as observed by Saha (2005). Rapid recovery in root dry weight could be seen after removal of waterlogging. Umaharan *et al.* (1997) found that the root dry weight increased in response to waterlogging during vegetative phase in cowpea. During 10 days recovery period, root dry weight from initial sample was reduced in the treatment T_3 (4-day waterlogged and received 25 kg K ha^{-1}) (0.24 g $plant^{-1}$) and the treatment T_5 (foliar spray with 1% urea solution + 25 kg K ha^{-1}) (0.29 g $plant^{-1}$). Root dry weight increased significantly in some treatments such as treatment T_2 (0.21 g $plant^{-1}$) (4-day waterlogged and received 14 kg N ha^{-1}) and the treatment T_4 (4-day waterlogged and combined application of 14 kg N ha^{-1} + 25 kg K ha^{-1}) (0.46 g $plant^{-1}$). Root dry weight in control treatment (T_1) was almost double (0.42 g $plant^{-1}$) during recovery period than that of initial sample (0.23 g $plant^{-1}$) taken at 0 DTF which might be due to allocation of more carbohydrate to the below ground portion as the plants developed adventitious roots to overcome waterlogging stress.

Laosuwan *et al.* (1994) suggested that the weight of the adventitious roots might be the best index for selecting tolerant genotypes in mungbean and blackgram genotypes under waterlogging situation. Root dry weight increased to a great extent at 20 DTF when the soil moisture receded and waterlogging stress was fully removed. The treatment T_4 (4-day waterlogged plants those received combined application of 14 kg N ha^{-1} N + 25 kg K ha^{-1}) had the highest root dry weight of 0.46 g $plant^{-1}$, which was statistically similar to the treatment T_1 (non-fertilized 4-day waterlogged plants) (0.45 g $plant^{-1}$) and the treatment T_2 (4-day waterlogged and received 14 kg N ha^{-1}) (0.40 g $plant^{-1}$). The treatment T_3 (4-day waterlogged and received 25 kg K ha^{-1} (0.38 g $plant^{-1}$) or the treatment T_5 (4-day waterlogged and received 1% urea foliar spray + 25 kg K ha^{-1}) (0.35 g $plant^{-1}$) produced lesser root dry weight than N treated waterlogged plants.

3.3. Total dry matter (TDM)

The total dry matter of mungbean genotype was markedly influenced by waterlogging and the variations of TDM in response to variable doses of N or K or their combinations were obvious (Table 2). After termination of flooding (0 DTF) till 10 days recovery period, TDM of flooded plants (T_2-T_5) with or without fertilization (T_1) did not make any significant difference. TDM increased a little extent in the treatment T_4 (4-day waterlogged and received combined use of 14 kg N ha^{-1} + 25 kg K ha^{-1}). The lowest TDM was produced in the control treatment T_1 (4-day waterlogged but non-fertilized plants). Application of N fertilizer in mungbean under normal growth condition increased TDM as reported by Akhtaruzzaman (1998). In the successive growth stages, it was observed that the treatment T_4 (4-day waterlogged and combine use of 14 kg N ha^{-1} + 25 kg K ha^{-1}) showed better performance from pod filling stage (20 DTF) and also at maturity (30 DTF). Increment in dry matter by nutrient combinations might be due to higher number of pod formation $plant^{-1}$ which accounted for high seed yield $plant^{-1}$.

3.4. Nutrient content

3.4.1. Nitrogen content

Nitrogen content in 4-day waterlogged plants fertilized with variable rates of N and K influenced the uptake of N at harvest (Table 3). N content was higher in treatment T_4 (4-day waterlogged and received combined application of 14 kg N ha^{-1}+25 kg K ha^{-1}) (3.39 %) followed by the treatment T_2 (4-day waterlogged and received 14 kg N ha^{-1}) (3.18%). The lower N content was recorded in the treatment T_5 (foliar spray with 1% urea solution + 25 kg K ha^{-1}) (2.94 %) and in T_1 (waterlogged control) (2.54%). Visually, it was observed that 4-day waterlogged plants suffered from N deficiency upto 10 DTF and thereafter became green. This implied that excess soil moisture interfered with the N_2 fixing activity of mungbean and above all, the tendency of a plant to save scarce N for the future reported by Trung *et al*. (1985).

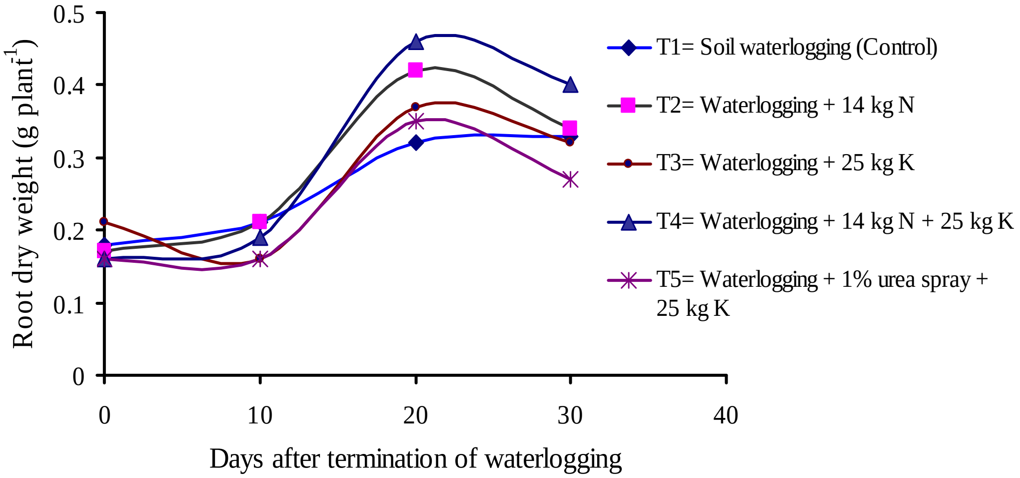

Figure 4. Root dry weight of mungbean genotype (IPSA-13) as influenced by N and K application after removal of waterlogging

Table 2. Total dry matter of mungbean as influenced by N and K application after removal of flooding

Treatment	Total dry matter (g $plant^{-1}$)			
	0 *DTF	10 DTF	20 DTF	30 DTF
T_1 (Soil waterlogging as control)	1.56	0.84	3.25	4.43
T_2 (Waterlogging + 14 kg N)	1.30	1.26	3.67	4.74
T_3 (Waterlogging + 25 kg K)	1.26	1.26	3.78	3.87
T_4 (Waterlogging + 14 kg N + 25 kg K)	1.60	1.45	4.49	5.62
T_5 (Waterlogging + 1% urea spray + 25 kg K)	1.25	1.33	3.55	4.66
$LSD_{0.05}$	0.243	0.207	0.706	0.493
CV%	11.45	9.40	9.98	5.68

*DTF=days after termination of flooding

Table 3. Effect of soil waterlogging on nitrogen, phosphorus and potassium content of mungbean genotype at harvest

Treatment	Nutrient content		
	N (%)	P (%)	K (%)
T_1 (Soil waterlogging as control)	2.542	0.107	1.407
T_2 (Waterlogging + 14 kg N)	3.183	0.123	1.601
T_3 (Waterlogging + 25 kg K)	2.360	0.132	1.662
T_4 (Waterlogging + 14 kg N + 25 kg K)	3.387	0.131	1.639
T_5 (Waterlogging + 1% urea spray + 25 kg K)	2.935	0.111	1.629
$LSD_{0.05}$	0.350	NS	0.171
CV (%)	8.49	5.63	7.20

3.4.2. Phosphorus content

Phosphorus content in the plant was determined from the composite sample and was statistically non-significant among the treatments (Table 3). 4-day waterlogging did not affect the plants available P content regardless of treatment when plants were fertilized with variable rates and methods of N or K nutrients. Devitt *et al.* (2012) reported that in the plant, Zn was unaffected and nitrogen, potassium, calcium, magnesium, and sodium decreased due to soil waterlogging.

3.4.3. Potassium content

Potassium content in the plant tissue was affected by waterlogging (Table 3). Waterlogged plants (T_2-T_5) had higher and statistically similar K content compared with that of plants grown under waterlogging without fertilization (T_1). The highest K content was recorded in the treatment T_3 (4-day waterlogged and received 25 kg K ha$^{-1)}$ (1.662 %). The lowest K content (1.407 %) was recorded in T_1 (4-day waterlogged plants where fertilizers were not applied). Sarder (1990) observed the greater K uptake of mungbean plants grown under low soil moisture regime.

3.5. Yield and yield components

Seed yield and yield attributes of mungbean grown under 4-day waterlogged conditions influenced by variable rates of N and K fertilizer (Table 4). Plant height of IPSA-13 at harvest varied significantly due to application of N and K fertilizers in 4-day waterlogged plants. Soil waterloggging reduced plant height but did not differ significantly among the waterlogged plants with (T_2-T_5) or without fertilization (T_1). The number of leaf plant^{-1} was statistically identical among the control (T_1) waterlogged and waterlogged fertilized plants (T_2-T_5) at harvest. Branching habit of mungbean might be genetically controlled. Waterlogged plants rarely produced a single branch plant^{-1}. Tariq *et al.* (2001) observed that application of P and K along with N increased plant height and number of branches plant^{-1}.

The number of pods plant^{-1} is an important yield character which accounts for higher seed yield. The number of pod plant^{-1} did not differ in fertilizer treated waterlogged plants. Treatment T_1 (4-day waterlogged plants without fertilization) produced the least number of pods plant^{-1} (3.10). Akhtaruzzaman (1998) reported that N fertilized mungbean produced increased number of pods plant^{-1}. The number of seeds pod^{-1} in waterlogged non-fertilized plants was statistically similar among fertilizer treatments (T_2-T_5). Seeds pod^{-1} of mungbean was positively correlated with seed yield grown in waterlogged-stressed condition (Islam, 1994). K had significant effect on number of seed pod^{-1} as reported by Abbas *et al.* (2011).

Table 4. Effect of N and K application on the yield and yield contributing characters of soil waterlogged mungbean

Treatment	Plant height (cm)	Leaf number plant^{-1}	Branch plant^{-1}	Pod plant^{-1}	Seed pod^{-1}	1000-seed weight (g)	Seed yield (g plant^{-1})	% yield relative to control
T_1	25.00	3.95	0.20	3.10	8.41	56.64	1.41	
T_2	28.05	3.85	0.25	4.22	8.24	59.71	2.11	49.7
T_3	25.30	4.20	0.20	3.63	8.20	60.60	2.11	49.7
T_4	27.40	3.65	0.20	4.58	8.33	60.68	2.34	66.0
T_5	27.95	4.15	0.20	4.22	7.97	60.20	2.07	46.8
$LSD_{0.05}$	NS	NS	0.067	0.943	NS	2.969	0.626	
CV (%)	10.77	13.84	14.85	14.23	6.97	3.28	17.54	

1000 seed weight of waterlogged fertilized plants (T_2-T_5) did not differ statistically and the smallest were produced in T_1 (4-day waterlogged but did not receive any fertilizer). This showed the beneficial effect of N and K fertilizers in waterlogged plants on the seed development of mungbean. The results are in agreement with that reported by Ardeshna *et al.* (1993) and Fatma *et al.* (2001).

Seed yield plant^{-1} differed significantly when waterlogged non-fertilized plants (T_1) was compared with waterlogged fertilized plants (T_2-T_5) (Table 4). The treatment T_4 (4-day waterlogged and received combine use of 14 kg N ha^{-1} + 25 kg K ha^{-1}) tended to produce higher seed yield (2.34 g plant^{-1}) than those of other fertilizer treated waterlogged plants but the differences were not significant. The lowest seed yield (1.41 g plant^{-1}) was produced in the control treatment T_1 (4-day waterlogged and did not receive any fertilizer). Plant nutrients (N and K) probably played an important role in the improvement of seed yield in waterlogged affected plants. N treated plants of mungbean yielded significantly better than the untreated control as observed by Akhtaruzzaman (1998). Tariq *et al.* (2001) found that application of 30: 30.8: 58.10 kg ha^{-1} N-P-K enhanced production of pods plant^{-1}, 1000-seed weight and gain the highest grain yield (876.32 kg ha^{-1}) of mungbean. According to Li *et al.* (2012) a regular granular dry fertilizer, such as 10 N-10 P_2O_5-10 K_2O, also can be used for waterlogged crops, but it was not as effective as foliar and liquid fertilizers.

4. Conclusions

The treatment T_4 (4-day waterlogged and received 14 kg N ha^{-1} + 25 kg K ha^{-1}) enhanced root growth and had higher N concentration but treatment T_3 (4-day waterlogged and received 25 kg K ha^{-1}) had higher K concentration of the plants after removal of waterlogging. Waterlogged plants when treated with combined application of N and K (T_4) produced maximum root dry weight, total dry matter and seed yield of mungbean. Additional application of nitrogen and potassium @ 14 kg N ha^{-1} and 25 kg K ha^{-1}, respectively separately or in combination, and 1% urea + 25 kg K ha^{-1} after termination of flooding, was found to mitigate waterlogging damage of the genotype IPSA-13. Therefore, N and K should be applied when stagnant water recedes from mungbean field.

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References

Abbas, G., Aslam, M., Malik, A. U., Abbas, M. A. and Hussain, F. 2011. Potassium sulfate effects on growth and yield of mungbean (V*igna radiata* L.) under arid climate. *Int. J. Agric. Appl. Sci.*, 3 (2): 72-75.

Aktaruzzaman, M. A. 1998. Influence of rates of nitrogen and phosphorus fertilizers on the productivity of mungbean (*Vigna radiata* (L.) Wilczek.) *Ph.D. thesis.* Bangabandhu Sheikh Mujibur Rahman Agricultural University. Bangladesh. 1-181 pp.

Ardeshna, R. B., Modhwadia., M. M., Khanpara, V. D. and Patel, J. C. 1993. Response of greengram (*Phaseolus radiatus*) to nitrogen, phosphorus and *Rhizobium* inoculation. *Indian J. Agron*., 38 (3): 490-492.

Ashraf, M. A., Ahmad, M. S. A., Ashraf, M., Al-Qurainy, F. and Ashraf, M. Y. 2011. Alleviation of waterlogging stress in upland cotton (*Gossypium hirsutum* L.) by exogenous application of potassium in soil and as a foliar spray. *Crop Pasture Sci.*, 62: 25–38.

Das, K. K., Panda, D., Sarkar, S. K., Reddy, J. N. and Ismail, A.M. 2009. Submergence tolerance in relation to variable floodwater conditions in rice. *Environ. Exp. Bot.*, 66: 425-434.

Davies, C. L., Turner, D. W., Dracup, M. and Hill, G. D. 1999. Waterlogging tolerance of yellow lupin (*Lupinus lutens*). *Proceedings of the 8th International Lupin Conference*, 11-16 May, 1996, Asilomar, California, USA.

Devitt, A. C. and Francis, C. M. 2012. The effects of waterlogging on the mineral nutrient content of *Trifolium sunterraneum*. Animal production Science. *Australian Journal of Experimental and Agriculture and Animal Husbandry*. CSIRO Publishing. 12(59): 614-617.

Drew, M. C. 1991. Oxygen deficiency in the root environment and plant nutrition. In: Jackson *et al.* (ed.) *Plant Life under Oxygen Deprivation.* Academic Publishing, The Netherlands Acad. Pub., The Hague. 303-316 pp.

Fatma, A. A., Fardoas, R. H. and Rizk, W. M. 2001. Effect of potassium fertilization on mungbean (*Vigna radiata* L.) Wilczek, *Egypt. J. Appl. Sci.*, 16: 156-167.

Glinski, J. and Stepniewski, W. 1985. Soil aeration and its role for plants. CRC. Press. 137-171 pp.

Gomez, K. A. and Gomez, A. A. 1984. Statistical procedures for Agricultural Research. 2nd edn. John Wiley and Sons. Singapore, 680 p.

Habibzadeh, F., Sorooshzadeh, A., Pirdashti, H. and Modarres-Sanavy, S. A. M. 2013. Alleviation of waterlogging damage by foliar application of nitrogen compounds and tricyclazole in canola. *Aust. J. Crop. Sci.*, 7(3): 401-406.

Hamid, A., Agata, W., Moniruzzaman, A. F. M. and Miah, A. A. 1991. Physiological aspects of yield improvement in mungbean. pp. 87-94. In: *Proceedings of the Second National Workshop on Pulses*, 6-8 Jan, 1989, Joydebpur, Bangladesh.

Hossain, M. A. and Uddin, S. N. 2011. Mechanisms of waterlogging tolerance in wheat: morphological and metabolic adaptations under hypoxic or anoxia. *Australian J. Crop Science*, 5(9): 1094-1101.

Huang, B., D. S. Nesmith, D.C. Bridges and J.W. Johnson. 1995. Responses of quash to salinity, waterlogging, and subsequent drainage. II. Root and shoot growth. *J. Plant Nutr.*, 18: 141-152.

Huang, B. 2000. Waterlogging responses and interaction with temperature, salinity, and nutrients. In: *Plant-Environment Interactions*, (ed.). R. E. Wilkinson, New York, Marcel Dekker, 1994. 263-282 pp.

Islam, M. R., Hamid, A., Karim, M. A. Ahmed, J. U, Khaliq, Q. A. and Haque, M .M. 2005. Response of mungbean to flooding at vegetative stage I. Root and shoot growth. *Bang. Agron. J.*, 11 (1&2): 1-9.

Islam, M. T., F. Kubota and W. Agata. 1994. Growth, canopy structure and seed yield of mungbean as influenced by water. *J. Fac. Agr.*, Kyushu Univ., 38(3-4): 231-224.

Kawsae, M.1981. Anatomical and morphological adaptations of plants to waterlogging. *Hort. Sci.*, 16(1): 30-34.

Kozlowski, T. T. 1984. Plant responses to flooding. BioScience 34: 162-167. *In:* Rubio *et al. Oecologia* (1995) 102:102-105.

Laosuwan, P., Mekanawakul, M. and Thonsomsri, A. 1994. The effects of waterlogging on growth development and yield of mungbean. *Suranaree J. Sci. Tech.*, 1(1): 9-14.

Li, Y., Rao, R. and Reed, S. 2012. Water management for vegetable production. Publication no. SL 206/SS425. U.S. Department of Agriculture, Cooperative Extension Service, University of Florida, IFAS, Florida. http://edis.ifas.ufl.edu.

McFarlane, D. and Glencross, R. 2012. Managing waterlogging and inundation in pastures. Farmnote 79/93. Dept. Agric. and Food. Govt. of Western Australia. http://www.agric.wa.gov.au/PC_92777.htm

Miah, A. A., Moniruzzaman, A. F. M. and Rahman, M. M. 1991. Problems and prospects of pulses production. Pp. 87-94. *Proceedings of the Second National Workshop on Pulses*, 6-8 Jan, 1989, Joydebpur, Bangladesh.

PPIC (Potash and Phosphate Institute of Canada). 1989. A booklet on Potash: its need and use in modern agriculture. The Potash and Phosphate Institute of Canada. Suskatchewan, Canada. 1-44 pp.

Rao R., Li, Y. and Bryan, H. H. 2002. Assessment of foliar sprays to alleviate flooding injury in corn (*Zea mays* L.). *Proc. Fla State Hort Soc.*, 115: 208-211.

Romheld, V. and Kirkby, E. A. 2010. Research on potassium in agriculture: Needs and prospects. *Plant Soil*, 335:155–180.

Saha, R. R. 2005. Physiological aspects of yield and seed quality of mungbean. (*Vigna radiata* (L.) Wilczek). *Ph. D. Thesis*. Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh.

Sarder, N. A. 1990. Establishment technique of mungbean (*Vigna radiata* L.) and sesame (*Sesamun indicum* L.) after rainfed wetland rice. *Ph. D. Thesis*. UPLB, Los Banos, Philippines.

Setter, T. L., Waters, I., Sharma, S. K., Singh, K. N., Kulshreshtha, N., Yaduvanshi, N. P. S., Ram, P. C., Singh, B. N., Rane, J., McDonald, G., Khabaz-Saberi, H., Biddulph1, T. B., Wilson, R., Barclay, I., McLean, R. and Cakir, M. 2009. Review of wheat improvement for waterlogging tolerance in Australia and India: the importance of anaerobiosis and element toxicities associated with different soils. *Ann. Bot.*, 103 (2): 221-235.

Steffens, D., Hütsch, B. W., Eschholz, T., Losak T. and Schubert S. 2005. Waterlogging may inhibit plant growth primarily by nutrient deficiency rather than nutrient toxicity. *Plant Soil Environ.*, 51: 545–552.

Tariq, M., Khaliq, A. and Umar, M. 2001. Effect of phosphorus and potassium application on growth and yield of mungbean. *On-line J. Biol. Sci.*, 1(6): 427-428.

Trought, M. C. and Drew, M. C. 1981. Alleviation of injury to young wheat plants in anaerobic solution culture and relation to the supply of nitrate and other inorganic nutrients. *J. Expt. Bot.*, 32: 509-522.

Trung, N. C., Yoshida, S. and Kobayashi, Y. 1985. Influence of excess soil moisture on the nitrogen nutrition and grain productivity of mungbean. *Japan J. Crop Sci.*, 54(1): 79-83.

Umaharan P., Ariyanayagam, R. P. and Haque, S. Q. 1997. Effect of short-term waterlogging applied at various growth phases on growth, development and yield in *Vigna unguiculata*. *J. Agril. Sci.*, Cambridge. 128: 189-198.

Zaidi, P. H., Maniselvan, P., Yadav, P. A. K., Singh, F., Sultana, R., Dureja. P., Singh, R.P. and Srinivasan, G. 2007. Stress-adaptive change in tropical maize (*Zea mays* L.) under excessive moisture stress. *Maydica*, 52: 159-171.