Grain legumes for food security- an adaptability study of mung bean (*Vigna radiata* (L.) Wilczek) genotypes for water deficit tropical environments

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ABSTRACT

This research was aimed to adapt some promising mung bean genotypes to water stress through a field based screening study which was conducted at the Field Crops Research and Development Institute, Maha Illupallama. Three mung bean breeding lines (MIMB 901, MIMB 902 and MIMB 903) and two local varieties namely MI6 and Ari were grown under three different irrigation regimes – i.e. full recommended irrigation (no water stress), half of the recommended irrigation (mild water stress) and rain fed condition (severe water stress). Water stress was imposed two weeks after sowing. Treatments were arranged in a split plot with three replicates with water regimes in main plots and genotypes as sub plots. Soil moisture was determined gravimetrically over the growth period. The maximum leaf area per plant (L_A) was calculated by periodic destructive sampling. Unit leaf net photosynthetic rate (P_n) was measured at flowering. Number of pods per plant (P), seed yield (Y) and harvest index (HI) were measured at the harvest. The data were analyzed with SAS 9.1 statistical package through analysis of variance procedures and least significant differences (LSD) at 0.05 probability was used for mean separation. Based on the tolerant characters, MIMB 901 could be a tolerant genotype under both mild and severe water stress conditions. MI 6 and MIMB 903 were moderately tolerant to both water stress conditions. In contrast, ARI was tolerant under mild water stress while moderately tolerant to severe water stress. MIMB 902 was identified as drought susceptible genotype under both water stress conditions. These tolerant traits could be incorporated in future crop improvements of mung bean while doing confirmatory studies in several locations.

Keywords: Irrigation, Mung bean, Susceptible genotype, Tolerant genotype, Water stress

1. INTRODUCTION

Grain legumes have long been considered as orphan crops with international research focusing mainly on globally important staples such as rice, wheat and maize. However, they are a vital source of protein for hundreds of millions of people unable to either afford or produce animal protein especially in the tropics. Even though the target date of Millennium Development Goals (MDGs) is closing by 2015, FAO (2012) indicated that 870 million people are chronically undernourished in 2010-2012 with the vast majority in the developing world and prevalence is high in South Asia (304 million) and Sub – Saharan Africa (234 million)[1]. Interestingly, in this region grain legumes are popularly cultivated by the small holders as a mixed, intercrop or in crop rotations because of their ability to fix atmospheric nitrogen which helps farmer to vitalize their depleted soils and to break the pest/disease cycles. Thus, grain legumes will be promising crops to eradicate protein malnutrition, poverty and hunger in the developing world.

Grain legumes are mostly grown as rainfed crops, during short rainy seasons and in marginal unfavorable environments, where the productivity is heavily challenged by water deficit which is likely to be exacerbated by climate change [2], [3]. Mung bean (*Vigna radiata*) is one of the popular grain legume crops in Sri Lanka, Consequently the current yields (i.e.1.17 Mt ha^{-1}) are significantly below the potential (i.e. around 3.0 Mt ha^{-1}) mainly due to water stress during various stages of growth [4]. Thus, there is a need to adopt mung bean crops to water deficit conditions to sustain their yield. Mung bean is known to have drought avoidance, drought escape and osmotic tolerance mechanisms to tolerate drought conditions [5], [6]. This field study aimed to screen better yielding varieties under water deficit environments to popularize those varieties among farmers to increase the nutritional security in Sri Lanka.

2. MATERIALS AND METHODS

The study was conducted at a location representing the low country dry zone of Sri Lanka (Maha Illuppallama- 8^{o} $6.65^{'}$ N and 80^{o} $27.84^{'}$ E), during the minor rainy season (*Yala*) of 2012. Three mung bean breeding lines (MIMB 901, MIMB 902 and MIMB 903) and two recommended varieties (MI 6 and ARI) were evaluated under three different irrigation regimes namely, full recommended irrigation (FR), half recommended irrigation (HR) and rain fed (RF). Irrigation was given to all irrigation regimes at four day intervals until the second week after seeding. Thereafter irrigation was given to full recommended treatment every four days in the first four weeks and every seven days thereafter, until eight weeks after sowing. Thus, this irrigation regime was the optimum (control) water supply (Department of Agriculture, Sri Lanka). The frequency was delayed by twice the interval of water supply to create a water deficit situation of half recommendation. Thus, water was applied every seven days from the second week until fourth week and every two weeks thereafter, until eight weeks after sowing (mild water stress). Rains fed plots were left without any irrigation after the second week (severe water stress). Treatments were arranged in a split plot with three replicates with water regimes in main plots and genotypes as sub plots.

Soil moisture was determined gravimetrically over the growth period. The maximum leaf area per plant (L_A) was calculated by destructive sampling at two week intervals. Unit leaf net photosynthetic rate (P_n) was measured using a LICOR 6400 Portable photosynthesis system at flowering. Number of pods per plant (P), seed yield (Y) and harvest index (HI) were measured at the harvest. The data were analyzed with SAS 9.1 statistical package through analysis of variance procedures and least significant differences (LSD) at 0.05 probability was used for mean separation.

3. RESULTS AND DISCUSSION

The cumulative total of the rainfall from seed sowing to harvest in the location was 2.3 mm (Source: Department of Meteorology, Sri Lanka). Therefore, gravimetric soil moisture content in the rainfed plots was reduced from second week after sowing since there was no irrigation and was measured only until sixth week after sowing because of the difficulties in taking the soil samples, while the changes in the gravimetric soil moisture content of the half recommended irrigation plots was lower than the full recommended irrigation plots and higher than the rain fed plots [Figure 1; left panel]. Thus the water stress to the crops under rainfed and half recommended regimes could be considered as severe water stress and mild water stress respectively.

Severe water stress (RF regime) and mild water stress (HR regime) significantly reduced the P_n, N and Y. The reductions for leaf area index, number of pods and seed yield of mung bean under water stress also reported by De Costa *et al*. (1999) [4]. Although, L_A is reduced due to water deficit the significant reduction was observed only under the rainfed regime. The impact of water stress was not evident on the harvest index. The genotypes showed significant differences in L_A under the HR regime, P_n under RF regime and on HI and Y under both water stress regimes. In contrast, genotypic variations were not evident on L_A in the RF regime, P_n under HR regime N under both water stress regimes.

Genotypic variation was also observed for number of seeds per pod and hundred seed weight (data not shown). Significantly higher values for above measured parameters were considered as tolerant (T), medium values as moderate (M) and lower values as susceptible (S) as shown in the Table 1. As shown in Figure 1; right panel, under mild water stress the genotype MIMB 901 and ARI had higher yield (\1.8-2.0 Mt ha^{-1}), MI6 and MIMB 903 had moderate yield (\1.6-1.7 Mt ha^{-1}) and MIMB 902 had lowest yield (\1.4 Mt ha^{-1}). The seed yield for MIMB 901 was highest (\1.2 Mt ha^{-1}), for MI6, ARI and MIMB 903 were moderate (\0.9-1.0 Mt ha^{-1}) and for MIMB 902 was lowest (\0.7 Mt ha^{-1}) under severe water stress. Even though MIMB 901, ARI and MIMB 902 showed tolerance in terms of maximum leaf area under mild water stress, the highest harvest index of MIMB 901 helped to increase the seed yield. Under severe water stress, tolerance was observed on unit leaf net photosynthetic rate for ARI, MI6 and MIMB 901 while higher values of harvest index were observed for MIMB 901 and MI6.

Table 1 Maximum leaf area per plant, unit leaf net photosynthetic rate at flowering, number of pods per plant and harvest index of mung bean genotypes as affected by different irrigation regimes

	Maximum leaf area / Plant (Cm^2)			P_n at flowering stage µmol [CO_2] m^{-2} [LA] S^{-1}		
Genotype	FR	HR	RF	FR	HR	RF
MI 6	709.3^a±94.7	505.7^c±113.3 **(S)**	324.8^a±147.9	30.7^a±4.4	24.1^a±6.6	23.7^a±3.2 **(T)**
ARI	750.9^a±76.9	681.8^{ab}±140.6 **(T)**	398.4^a±33.4	23.2^{ab}±5.2	19.8^a±5.4	24.1^a±1.5 **(T)**
MIMB 901	782.1^a±107.8	705.2^{ab}±80.3 **(T)**	417.5^a±57.4	24.6^{ab}±5.2	22.2^a±0.8	19.6^{ab}±3.3 **(M)**
MIMB 902	714.5^a±63.1	825.5^a±15.5 **(T)**	459.7^a±76.4	21.0^b±7.2	18.6^a±2.1	17.6^{bc}±0.5 **(M)**
MIMB 903	764.5^a±88.7	653.1^{bc}±59.0 **(M)**	335.3^a±118.8	30.6^a±1.1	21.7^a±4.6	13.4^c±3.7 **(S)**
Mean	744.3	674.3	387.2	26	21.3	19.7
LSD$_W$	122.2			3.74		
LSD$_G$	159.4	168.3	174.9	9.1	8.1	5
CV (%)	12.8			18.6		

	Number of pods per plant			Harvest index (%)		
Genotype	FR	HR	RF	FR	HR	RF
MI 6	14.0^{bc}±1.6	11.7^a±1.0	6.8^a±1.4	29.7^a±3.2	26.7^{ab}±1.5 **(M)**	26.3^a±2.3 **(T)**
ARI	22.3^a±0.9	13.9^a±1.7	8.6^a±1.9	31.0^a±2.6	25.3^{ab}±6.5 **(M)**	24.0^{ab}±4.4 **(M)**
MIMB 901	15.7^{bc}±2.9	13.3^a±0.8	7.9^a±1.0	31.3^a±2.5	29.3^a±2.9 **(T)**	25.7^a±1.2 **(T)**
MIMB 902	13.5^c±1.5	14.0^a±2.5	7.5^a±2.3	27.3^a±2.3	24.3^{ab}±4.9 **(M)**	20.3^b±2.9 **(S)**
MIMB 903	18.2^{ab}±4.3	13.0^a±1.9	7.7^a±0.5	28.0^a±1.7	20.0^b±5.3 **(S)**	25.3^{ab}±2.5 **(M)**
Mean	16.7	13.2	7.7	29.5	25.1	24.3
LSD$_W$	3.1			5.6		
LSD$_G$	4.6	3.1	2.8	4.6	8.4	5.2
CV (%)	13.8			7.4		

Note: LSD$_G$ = LSD (p=0.05) for the comparisons of genotypes within a water regime (means with same letters are not significantly different); LSD$_W$ = LSD (p=0.05) for the comparisons of mean values between water regimes; T, M and S indicates Tolerance, Moderate and Susceptible character in each parameter under the water stress regimes respectively

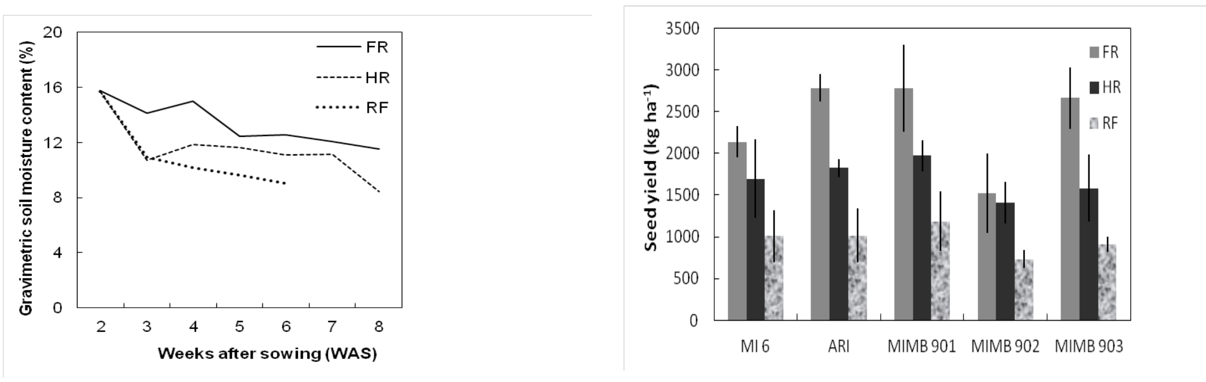

Fig. 1 Changes in gravimetric soil moisture content (left panel) and seed yield of mung bean genotypes (right panel) under the adopted irrigation regimes

4. CONCLUSIONS

MIMB 901 could be a tolerant genotype under both mild and severe water stress conditions. MI 6 and MIMB 903 were moderately tolerant to both water stress conditions. In contrast, ARI was tolerant under mild water stress while moderately tolerant to severe water stress. MIMB 902 was identified as drought susceptible genotype under both water stress conditions even though it developed a comparable higher leaf area. Before using these valuable drought tolerant traits for genetic improvement and breeding, they should be further investigated on a large scale research together with the investigation for tolerance of other common abiotic and biotic stresses and some quality traits such as hard seed percentage to popularize them via sustaining the yields of mung bean.

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