Effect of drought stress on mungbean (*Vigna radiata* L.) under arid climatic conditions of Saudi Arabia

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Abstract

Water limitation is undoubtedly a critical environmental constraint hampering crop production in arid and semiarid areas. The present study was conducted to assess the water deficit stress consequences of yield components and water use efficiency (WUE) in mungbean. A field experiment was conducted at Educational Farm, Crop Production Department, College of Food and Agriculture Sciences, Kind Saud University, Saudi Arabia during 2012–2013. The trial was comprised of four irrigation intervals viz. (3, 5, 7 and 9 day intervals) as well as three mungbean genotypes; Kawmay-1, VC-2010 and King. The experiment was arranged under split plot design with irrigation as the main plot and genotype as subplot treatment, and replicated thrice. Plant height, 100 seed weight, biological yield, seed yield, harvest index and WUE were recorded at harvesting. Results revealed that a decrease in irrigation had significantly hampered all the studied parameters except WUE. The differences found among mungbean genotypes were significant. Whereas irrigation-genotype interaction was significant for seed yield, harvest index and WUE. Plant height, shoot weight and biological yield were recorded as non-significant for irrigation-genotype interaction. The minimum irrigation interval (3 days) produced the maximum values, while VC-2010 comparatively performed best under low irrigation levels. It is concluded that mungbean may be successfully adopted under the Saudi Arabian climate, but it needs frequent irrigation. However, genotypic variations are a hope to developing improved varieties with a higher WUE.
Keywords: mungbean, irrigation intervals, water use efficiency, genotypes, yield.

WIT Transactions on Ecology and The Environment, Vol 192, © 2015 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/ECO150171

1 Introduction

Drought is a meteorological term and is commonly defined as a period without significant rainfall. Drought stress changes the biochemical and physiological reactions, pigment composition and morphological characters of plants [1, 2]. In arid and semiarid regions, water deficit is a major crop restraining factor. Limited amounts of water, low and irregular rainfall, and hot summers promote drought stress which are the world leading intimidations that should be considered [3, 4]. Water scarcity and increasing demand create an urgent need for improved irrigation management to maximize the efficiency of available precious water resources. The development of new irrigation scheduling such as deficit irrigation is one of the options available to increase per unit yield [5]. However, the yield response of the crop to deficit irrigation must be in an investor's knowledge [6]. Both over-irrigation and deficit irrigation are economically unsuitable. Over-irrigation wastes water, energy and labour, it may also lead to water-logging, nutrient leaching and low yields while drought stress can cause severe yield reduction [7]. Hence an accurate and wise use of irrigation has been suggested for arid and semiarid regions.

Mungbean or green gram (*Vigna radiata* L.) is an annual grain legume, widely spread in Asia and an important component of many major cropping systems [8]. Fresh or dry mungbean seed can be used as a whole or may be processed to bread, noodles, porridge, soups, snacks or even ice-cream [9]. It's a fat free, protein rich meat replacer especially for vegetarians, and in addition it contains a variety of minerals and vitamins [10]. It can be used as intercrop or a cover crop in-between two cereal crops due to its short growing period (80–90 days) [9, 11]. It can be grown under limited amounts of water and poor soil fertility. It is also a valuable green manure, can produce a huge biomass (7.16 t/ha) [12] and contributes a lot of nitrogen to soil ranging from 30 to 251 kg/ha [13, 14]. Mungbean straw and by-products are fairly good and valuable feed for sheep and goats [15], cattle [16], poultry [17] and fish [18]. Mungbean does not require a large amount of irrigation water (600–1000 mm/year rainfall) and is also capable of tolerating drought stress [9] as it has a well-developed root system including taproot and deep lateral roots for the absorption of water when limited in availability [8]. Some of the experimental studies believe that drought stress has no effect on mungbean as it is a drought tolerant crop. However, a few studies have been undertaken to investigate the negative effects of drought stress on the growth, physiology, yield and yield components of mungbean [19, 20].

Drought resistance is a complex quantitative trait, involving interactions of many metabolic pathways related to stress-resistant genes. One strategy to reduce the effect of water stress on crop yield is to use drought tolerant genotypes and is a good management of irrigation water supplies. This assertion was supported by Siddique *et al.* [21], who reported that for the purpose of crop production, yield improvement and yield stability under water stress conditions, development of drought tolerant varieties is the best option. Crop plants are usually under stress at one time or another and plant species able to withstand such stresses have great economic potential [22]. Use of drought tolerant species is one of the effective strategies used to cope with water deficit stress wisely, as some plants species are able to withstand such stresses [21–23]. The proper application of deficit irrigation practices can generate significant saving in irrigation water supplies [21, 24]. Among field crops, groundnut, soybean, common bean and sugarcane have shown proportionately less yield reduction under continuous but lower drought stress than the relative evapotranspiration deficit imposed at certain growth stages. The present study was designed to identify the yield potential of promising mungbean genotypes under a controlled deficit water supply.

2 Materials and methods

2.1 Experimental site

The field experiment was conducted at Educational Farm, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia during summers 2012–13. The experimental site was located in tropical arid at 24.72°N latitude, 46.63°E longitude and almost 600m altitude. This region has a hot desert climate, an extremely hot summer, approaching 50°C occasionally and with only 10 to 17 percent humidity. The city experienced very little rainfall and a number of heavy dust storms in the summers.

2.2 Plant materials

Three mungbean genotypes were selected for the current experiment from 20 genotypes previously evaluated by, Field Crop Group, Plant Production Department, College of Food and Agricultural Sciences, in a series of experiments conducted under the title of "introduction of new crops under Saudi Arabian condition". This selection was based on yield and yield component characters. In the present study the following three genotypes have been selected:

Table 1: Mungbean genotypes and origin.

Number	Genotype name	Origin
V_1	Kawmay-1	Egypt
V_2	VC-2010	Thailand
V_3	King	China

Healthy seeds were sorted out mechanically and treated with 0.1% sodium hypochlorite (NaOCl) for 5 minutes then washed with distilled water. Air dried seeds were then measured by an electric balance to maintain the weight of seeds for each treatment and packed for each pot separately.

2.3 Soil analysis and preparation

Before commencement of the field experiment, soil samples were taken from 30–60 cm depth for physical and chemical analyses according to the methodology described by Cottenie *et al.* [25] and But [26]. Results revealed that the soil site was sandy-clay-loam in texture with electrical conductivity 1.4 dS/m^{-1}. The seedbed was prepared according to the recommendations of the Ministry of Agriculture, Saudi Arabia. The soil was ploughed twice and divided into plots, subplots, paths and borders. Phosphate fertilizer was applied as calcium superphosphate (15.5% P_2O_5) by the rate of 200 kg/ha and potassium fertilizer as potassium sulphate (48% K_2O) @ 150 kg/ha while nitrogen sulphate (20.6% N) @ 50 kg N/ha was applied in three split doses.

2.4 Field experiment:

The field experiment was arranged under the split plot design according to Gomez and Gomez [27] with three replications. The experiment included 36 experimental units, four drought stress levels imposed as the irrigation interval (illustrated below in Table 2) as main plots and three genotypes V1 (Kawmay-1), V2 (VC-2010) and V3 (King) in subplots. Each subplot had dimensions 3m x 2m with 6 m^2 total area. Seeds were planted manually in 10 cm apart hills while row to row distance was kept at 50 cm. Fifteen days after sowing, hoeing and thinning were done to eradicate weeds as well as 3 seedlings per hill were maintained. The same amount of water was applied at every irrigation (about 400 m^3/ha), which was previously determined based on field capacity. The amount of irrigation was regulated by using a "gauge meter". The soil moisture content was measured by a "moisture probe meter" (MPM-160-B) based on water volume percentage (%) for each treatment. Drought stress treatment was started three weeks after sowing. Amounts of irrigation water supplied over the growing season were calculated and are presented below (Table 2).

Table 2: Irrigation plan, interval and total amount of irrigation.

Treatment number	Irrigation interval (days)	Number of irrigations	Amount of irrigation (m^3/ha)
I_1	3	30	12000
I_2	5	18	7200
I_3	7	13	5200
I_4	9	10	4000

2.5 Observations

At harvesting; Plant Height (cm), Shoot Dry Weight (ton/ha), Biological Yield (ton/ha), Seed Yield (kg/ha) and Harvest Index were measured according to standard protocol. Water use efficiency (WUE) (kg/m^3) was computed according to the following equation formulated by Bos [28].
WUE_b = Biological Yield/Seasonal water use

2.6 Statistical analysis:

The data obtained was subjected to the statistical analysis suggested by Gomez and Gomez [27] and wherever the treatment differences were found to be significant (F-test), critical differences were worked out at the five per cent probability level. Means were compared by using the Least Significant Difference test (LSD), with a 0.05 level of significance, which was developed by Steel *et al.* [29].

3 Results and discussion

Water deficit stress is one of the most rapidly increasing threats to agricultural production. Limited amounts of water, increasing demand and deterioration of available water reservoirs are the fundamental factors to be considered. Efficient utilization of this precious agricultural input is one of the most cost-effective options for arid and semiarid regions. The present study disclosed that irrigation interval and genotypic differences were highly significant while genotype by irrigation interaction was found to be highly significant for seed yield, harvest index and WUE, while plant height, shoot weight and biological yield were found to be non-significant (Table 3).

Table 3: Analysis of variance summary for mungbean genotypes under water deficit stress.

Sources of variations	Shoot weight (ton/ha)	Harvest index (%)	Plant height (cm)	Seed yield (kg/ha)	WUE_b (kg/m^3)	Biological yield (ton/ha)
Irrigation(I)	3.73**	467.31**	881.30**	1,843,053**	0.505**	6.23**
Genotype(G)	11.89**	64.05**	181.57**	213,659**	0.163**	5.79**
I x G	0.19ns	5.80*	11.56ns	8,956**	0.009*	0.055ns
CV (I x G)	14.57	12.51	10.68	2.84	9.37	12.56

*, and **:F-test significant at $P \leq 0.05$, and $P \leq 0.01$, respectively. ns, not significant.

Irrigation was recorded as highly significant for all study parameters. However, biological yield was recorded as statistically similar for I_1 and I_2. Irrigation frequently resulted in descending order $I_1>I_2>I_3>I_4$ for shoot weight, HI, plant height, seed yield; however, WUE showed a reverse trend, it has been recorded as increasing when water deficit stress is increased (Table 4). This may be the result of hampered physiological processes under deficit water conditions. These findings were in line with the results of Mogotsi [9], who reported that seed yield and WUE of mungbean were affected by the irrigation amount. The genotypic variations in mungbean are have shown varied behaviour under similar water conditions. Kawmay-1 performed excellently for plant height, VC-2010 lead in biological yield, seed yield and WUE; whereas for harvest index both were statistically similar. The "King" genotype was statistically similar to VC-2010 for shoot weight and biological yield. The minimum irrigation interval and maximum amount of water applied have produced better yields under the arid climatic conditions of Saudi Arabia. However, conclusively, VC-2010 performed better under all water deficit condition. Siddique *et al.* [21] and Bibi *et al.* [22] reported similar results and concluded that genotypic differences within a species have remarkable potential for crop improvement under water stress conditions.

Table 4: Mungbean genotypes performance under water deficit stress in Saudi Arabia.

Irrigation	Shoot weight (ton/ha)	Harvest index (%)	Plant height (cm)	Biological yield (ton/ha)	Seed yield (kg/ha)	WUE $_b$ (kg/m^3)
I_1	4.78 A	18.86 A	48.77 A	6.14 A	1129.2 A	0.511 C
I_2	4.73 A	11.33 B	44.59 B	5.59 A	623.1 B	0.777 B
I_3	4.51 AB	05.27 C	37.55 C	4.89 B	256.9 C	0.941 A
I_4	3.98 B	02.65 D	26.15 D	4.22 C	115.2 D	1.058 A
LSD	0.653	1.8950	0.8225	0.25	21.050	0.1271
Varieties						
Kawmay-1	3.76 B	10.99 A	43.71 A	4.45 B	515.78 B	0.697 C
VC-2010	4.97 A	10.74 A	36.49 B	5.82 A	671.56 A	0.927 A
King	3.78 A	06.87 B	37.60 B	5.36 A	406.01 C	0.841 B
LSD	0.565	1.8572	1.71	0.26	6.16	0.0666

Biological yield is the outcome of plant health and growth. The present study revealed that the mungbean genotype, Kawmay-1 produced the maximum biological mass when under the highest and most frequent irrigation application (Table 5). The harvest index, a quick expression of economic production, was led by the I_1 x Kawmay-1 and I_1 x VC-2010 pairs respectively while the genotype "King" had the minimum harvest index when under the lowest irrigation (I_4) (Table 5). The harvest index of the expressed parameters viz. physiological and genetic components as well as genotypic variations x environmental interaction, are affected by water deficit stress. The Kawmay-1 genotype produced the maximum plant height and biological yield under I_1 while "King" stood highest in shoot weight. However, almost all other combinations overlap one another for these parameters. Although growth was recorded as non-significant it was found that, in G x I, I_4 consistently hampered the growth of all three mungbean genotypes (Table 5). Plant height, biological yield and shoot weight are the indirect measure of the vegetative health of plants which are vulnerable to environmental stresses and based on genome properties. Seed yield is the most desired character of farmer's interest in field crops and considered as the economic outcome of farming. The VC-2010 genotype in combination with I_1 was recorded as having the highest seed yield followed by Kawmay-1 and "King", respectively, under the same irrigation conditions (Table 5). Here again the gradual increase in water deficit conditions regularly reduced the seed yield for all three genotypes. These findings corroborated the results reported by Hao *et al.* [23] who stated that irrigation stress may reduce the mungbean seed yield and affect WUE. WUE: the major object of this research and the aggregate of all physiological, genetic and phonological mechanisms of plants under certain situations was recorded as highest for VC-2010 and I_4 combination followed by Kawmay-1. A clear distinction can be seen in different interactions for WUE efficiency (Table 5); it has increased as the amount of seasonal irrigation water decreased, and is an area for future study. Shirvan and Asgharipur [19] and Ranawake *et al.* [20] are in support of the present findings. A plants response to unusual stresses is simultaneously a mixture of the multidisciplinary networked correlation among different plant processes and genetic combinations.

Table 5: Genotype-irrigation interaction summary of mungbean under the Saudi Arabian climate.

Interaction I x G	Shoot weight (ton/ha)	Harvest index (%)	Plant height (cm)	Biological weight (ton/ha)	Seed yield (kg/ha)	WUE $_b$ (kg/m^3)
I_1 x Kawmay-1	5.09 AB	22.04 A	55.94 A	6.64 A	1146.9 B	0.45 G
I_1 x VC-2010	5.10 AB	19.78 A	43.73 BC	5.43 BCD	1306.6 A	0.55 FG
I_1 x King	5.18 A	14.78 B	46.66 BC	6.35 AB	934.2 C	0.52 FG
I_2 x Kawmay-1	3.87 CD	12.53 B	49.30 B	4.53 DE	583.6 E	0.65 EF
I_2 x VC-2010	5.16 AB	12.85 B	41.74 CD	6.17 AB	784.4 D	0.86 CD
I_2 x King	5.17 AB	08.60 C	42.75 BC	5.90 ABC	501.3 F	0.82 CD
I_3 x Kawmay-1	3.84 CD	06.10 CDE	41.46 CDE	4.22 EF	254.2 H	0.65 DE
I_3 x VC-2010	5.01 AB	07.21 CD	35.26 E	5.52 BCD	394.3 G	1.06 B
I_3 x King	4.68 ABC	02.49 EF	35.92 DE	4.93 CDE	122.1 I	0.97 BC
I_4 x Kawmay-1	3.27 D	02.28 F	28.16 F	3.47 F	78.4 IJ	0.87 CD
I_4 x VC-2010	4.61 ABC	04.10 DEF	25.24 F	4.93 CDE	200.9 H	1.12 A
I_4 x King	4.08 BCD	01.59 F	25.06 F	4.26 EF	66.4 J	1.07 B
LSD	1.13	3.71	3.42	0.53	12.32	0.13

4 Conclusion

The present study revealed that mungbean could be successfully cultivated in a Saudi Arabian climate. However, deficit irrigation is a serious limiting factor. Mungbean biological yield, seed yield, shoot weight, plant height, harvest index and WUE were affected by the amount of irrigation. Although water deficit stress has hampered the yield and yield components of mungbean. However, the VC-2010 genotype has performed better under all irrigation levels and may be used for further research and varietal development programs.

Acknowledgement

The authors are thankful to the Deanship of Scientific Research, College of Food and Agricultural Sciences, King Saud University, Saudi Arabia for financial support and cooperation in completion of this research.

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