



## Mitigation of drought stress effect on growth and productivity of mung bean by foliar application of sorghum water extract

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### Abstract

Field trial was conducted in Research Field equipped with rainfall transparent shade, Biology Department, College of Science, Baghdad University during the growing season of 2012 to test the potential of sorghum water extract in improving yield and yield components of local cultivar of mung bean crop grown under different moisture deficit stresses. The water stresses were applied by irrigated the plots to field capacity and withheld the next irrigation until the soil water deficit reaches 80, 50 and 30% of field capacity for control, mild water stress and higher water stress, respectively. Foliar application of sorghum water extract at 0 ( control), 2.5 and 5% (W/V) was made at preflowering, flowering and fruiting stages. The experiment was conducted in split plot design with four replications for each treatment. The sorghum water extract rates were kept in the sub plot while moisture deficits were assigned as main plot.

Results showed that drought stress significantly reduced the averages seed yield , dry matter accumulation, number of pods per plant, number of seeds per pod and plant height. Foliar applications of sorghum extracts significantly increased seeds yield, dry weight biomass, number of seeds per pod and plant height. The interaction of drought stress and sorghum water extract treatment significantly affected seed yield , dry matter accumulation, number of pods per plant, total chlorophyll content and plant height. Application of sorghum water extract under severe moisture deficit stress (i.e., 70% field capacity) increased seed yield, dry weight biomass and plant height , number of pods per plant, number of seeds per pod by 37.8%, 48.9%,64.3%,8.7% and 5.1%, of control, respectively compared the reduction achieved by the sever moisture deficit applied alone which was 58.50% , 56.06% , 57.17% , 48.05% and 14.78 % of control for the aforementioned parameters respectively.

Chlorophyll content was found to be increased by effected by application of sorghum extracts at control moisture treatment. Proline content of leaves was significantly increased by high drought stress when water extract applied alone. However, such differences disappeared when sorghum extract was applied, suggesting another mechanisms could be responsible for the stimulatory effect of sorghum extract under drought stress.

**Key words:** drought mitigation, sorghum extract, mung bean, yield

## تخفيف تأثير الجفاف في نمو وحاصل الماش بالرش بالمستخلص المائي للذرة البيضاء

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### الخلاصة

نفذت تجربة حقلية في حقل بحوث قسم علوم الحياة في كلية العلوم، جامعة بغداد خلال الموسم الزراعي ٢٠١١ لاختبار الجهد الأليلوبيائي لتراكيز منخفضة من المستخلص المائي للذرة البيضاء في تحسين

نمو وإنتاجية محصول ألبان النامي تحت شتدود مختلفة من نقص ماء التربة. إذ نفذت التجربة في حقل مزود بغطاء نافذ للضوء لوقاية التجربة من ماء المطر، قسم الحقل إلى ألواح مساحة الواحد منها 2×1م وزرعت بذور ألبان وفق التوصيات الخاصة للمحصول. تم سقي النباتات في بداية التجربة إلى السعة الحقلية ثم حجبت السقية التالية إلى أن وصل نقص ماء التربة إلى 20 (المقارنة) و 50 و 70% من السعة الحقلية واستمر العمل بهذه الطريقة إلى نهاية التجربة. تم رش ثلاثة تراكيز من المستخلص المائي للذرة البيضاء وهي صفر ( ماء مقطر للمقارنة) و 2,5 و 5% (وزن / حجم) وواقع ثلاث رشات الأولى قبل التزهير والثانية بعده و الثالثة في مرحلة تكون القرينات، نفذت التجربة وفق تصميم الألواح المنشقة بثلاثة مكررات ، إذ مثلت المستخلصات الألواح الثانوية في حين تمثلت معاملات الجفاف بالألواح الرئيسية.

أظهرت النتائج وجود اختزال معنوي في متوسط حاصل البذور و الحاصل البيولوجي وارتفاع النبات وعدد القرينات في النبات. في حين أدى الرش بالمستخلصات إلى زيادة معنوية متوسط حاصل البذور و الحاصل البيولوجي وعدد القرينات في النبات وعدد البذور في القرنة وارتفاع النبات. وقد بينت النتائج وجود تداخل معنوي بين معاملات الجفاف ومعاملات المستخلص المائي بالنسبة لحاصل البذور والحاصل البيولوجي وارتفاع النبات وعدد القرينات في النبات. ويلاحظ أن الرش بالمستخلص المائي قد ساهم في اختزال نسبة الانخفاض العالية التي سببها شد الجفاف لوحده في اغلب الصفات المدروسة، فمثلا اختزل شد الجفاف العالي حاصل البذور والحاصل البيولوجي وعدد القرينات وارتفاع النبات بنسبة 58,5% و 56,1% و 57,2% و 48,1% عن معاملة المقارنة على التوالي، في حين انخفض الاختزال في تلك المؤشرات إلى 37,8% و 48,9% و 64,3% و 8,8% عن معاملة المقارنة عند الرش بالتركيز 5%، الأمر الذي يشير إلى أن الرش بالمستخلص قد ساهم بشكل واضح في تخفيف تأثير الجفاف في نمو وإنتاجية محصول ألبان. ولوحظ من الدراسة أن محتوى الأوراق من الكلوروفيل والبرولين لم يختلف معنويا في معاملتي الجفاف والمستخلصات والتداخل بينهما ، الأمر الذي يشير إلى احتمال وجود آليات أخرى وراء التخفيف الحاصل من رش المستخلص المائي للذرة البيضاء لشد الجفاف.

## Introduction

Drought is the most limiting factor that reduces agricultural production in arid and semiarid regions of the world which covers more than 40% of global land. The rapid growing world population and the adverse impacts of climate change have led to growing competition for water use by industrial and urban users for agriculture to secure enough food. Irrigated agriculture is an important role in total agriculture and provides humanity with a wide range of agricultural products, including fruits, vegetables, grains and cereals. Different approaches have been used to reduce the damages caused by drought such as selection of high water use efficiency and drought resistant cultivars, use of growth regulators (GA<sub>3</sub>, IAA and cytokinins) and seed treatments with osmoprotectants [1,2,3 and 4]

Recently, few reports indicated the possibility of using natural crude chemical compounds to reduce the adverse effect of drought stress on plant. Makkar and Becker [5] found that using of *Moringa oleifera* L. leaves water extract was found to be a potential source to mitigate the deleterious effect of drought on maize. They further indicated that the water extract contains growth promoters which may reduce the adverse effect of drought by delaying

the leaf senescence and scavenging the oxygen molecules. Others found that the lower concentrations of water extract has stimulatory effect on plant growth [6]. Maqbool. [7] found that foliar application of lower concentration of sorghum (Water extract of sorghum) significantly stimulated growth and productivity of maize.

Mung bean is cultivated during summer season in Iraq which dominates by drought and high temperature environment. The productivity of this crop is reported to be reduced drastically by drought condition [8]. Therefore, searching for improve growth and yield of this crop when grown under drought condition would be a vital task. The present investigation was carried out under field condition to test the effect of foliar application of different concentrations of sorghum water extracts on growth and productivity of mung bean grown under different water stresses and to study the effect of sorghum extracts alone or in combination with drought stresses on some physiological parameters related to drought stress.

## Materials and Methods

### Plant Materials

Mature plants of *Sorghum bicolor* L. (Moench) were taken from the field of Department of Field Crop Production, College of Agriculture, Baghdad University, Iraq. The

plant parts (stem and leaves) were air dried under plastic shed for several days and chopped into pieces of about 1 cm long and kept under laboratory condition until use.

#### Preparation of Sorghum Extracts

For preparation of sorghum water extracts, 300 g of the chopped plant materials were added to 3000 ml of boiling distilled water for 5 minutes, shaken by hand for 10 minutes and allowed to stand for one hour. The extract was filtered by cheese cloth to remove the sorghum debris. The filtrate was diluted with appropriate amounts of distilled water to obtain final concentrations of 2.5 and 5 % (W/V). Distilled water was used as a control.

#### Field Study

Field experiment was conducted at Research farm, Department of biology, College of science, Baghdad University, Baghdad. The field is characterized by calcareous loamy sand soil of pH 7.2 and electrical conductivity 1.1 dS m<sup>-1</sup>; average day/night temperatures during the growing season were 230 – 45/ 25 – 235°C.

Field plots (2 × 1 m) were made randomly in the field equipped with transparent shed to avoid rain. These plots were plowed by a spade to a depth of 30 cm and separated from each other by a plastic sheet inserted vertically in the soil to 35 cm depth in order to prevent the possible horizontal movement of soil water. Seeds of mung bean cv. local were manually sown in all plots in 40 cm spaced rows keeping 25 cm distance between plants (10 plants per m<sup>2</sup>). Nitrogen as urea (46% N) at 20 kg ha<sup>-1</sup> and phosphorus as triple super phosphate (46% P<sub>2</sub>O<sub>5</sub>) at 80 kg ha<sup>-1</sup> were applied to the plots. All phosphorus and half of the nitrogen were applied at planting during seed bed preparation. While remaining nitrogen was applied after 2 weeks from sowing. The treatments were comprised of three stress levels and three sorghum water extracts. The water stresses were applied by irrigated the plots to field capacity and withheld the next irrigation until the soil field capacity reaches to 50%, 25% and 15% for control, water stress level #1 and water stress level # 2, respectively. Field soil water capacity was determined by weight basis method [9]. Water stress levels and sorghum water extracts {0 (control), 0.25 and 0.5 % (w/v)} were applied either alone or in combination with each other. The extracts plus very little amount of detergent as a surfactant were sprayed by hand sprayer directly over plants (30 cm above the plant) of the respective plots at pre flowering, flowering

and fruiting stages. Crop management practices such as thinning, hand weeding and pesticides application were made as per requirement. The experiment was conducted in randomized complete block design under split plot arrangement with three replications. The drought levels were kept in the main plots while sorghum extract concentrations were assigned to subplots. The data were analyzed by analysis of variance technique. The least significant difference test was used to compare the averages of treatments [10].

#### Physiological parameters

At flowering stage, total chlorophyll content of leaves of five randomly selected mung bean plants within each plot was measured using the method of Arnon [11]. A sample of 0.25 g of fresh weight leaves tissue was extracted with 10 ml acetone. The extract was centrifuged at 3000 rpm for one minute and the filtrate was taken and completed to 10 ml of appropriate amount of acetone. The optical densities of the extracts was read at wavelength 642.5 and 660 nanometers by U.V.VIS. spectrophotometer. 3000 plus OPTIMA JAPAN. Total chlorophyll were determined by the following equation:

$$\text{Total Chlorophylls mg/g fresh weight} = (7.12 \times A_{660}) + (16.8 \times A_{642.5}) \times 100 / 1000 \times .25$$

Free proline content in the leaves was determined following the method of [12]. The method is based on proline reaction with ninhydrin reagent. For proline colorimetric determination, a 1:1:1 solution of proline, ninhydrin acid and glacial acetic acid was incubated at 100°C for one hour in water bath. The reaction was arrested in an ice bath and the chromophore was extracted with 5 ml toluene and its absorbance was read by spectrophotometer (Varian Australia PTY LTD) at 520 nm. Proline concentration was determined using a calibration curve and expressed as μ mol proline g<sup>-1</sup> FW and modified to μ g proline g<sup>-1</sup> FW.

μ mol of proline/g of fresh weight = [( μ g proline/ml × ml toluene / 115.5 μ g / μ mol )] / [( g samples / 5 )].

#### Agronomic traits parameters

At physiological crop maturity (75 days after sowing), five randomly selected plants from each plot were used to measure plant height (cm), number of branches per plant and dry weight accumulation. Plant height was made by measuring the distance from plant base to the

tip of main stem. For determination of dry weight accumulation, the aboveground materials were harvested, after taking the pods, then dried at 60 °C for three days and weighed.

#### Yield and Yield Components parameters

The number of pods per plant was measured by taking the pods of the 10 selected plants then averaged. For measuring of 100-seed weight, three samples of 100 seeds were randomly taken from the seeds of the 10 plants and weighed by electrical balance then averaged. Seed yield was recorded by measuring the weight of the seeds of the 10 plants which was selected from each plot.

#### Results

##### Effect of sorghum water extracts on grain and yields and biomass yield of mung bean grown under different water deficit stresses

Results presented in table 1 revealed that average yield was significantly reduced by 49.9% and 58.5 % of control by 50 and 70% water deficit respectively. However no significant difference was found between the two water deficit stress. Application of sorghum water extracts significantly increased average yield by 50.0% and 45.3 % of control.

The interaction between water deficit stress and sorghum extracts significantly affected yield of mung bean. At zero extract treatment (control), mung bean yield was reduced up 53.17% and 65.38% by 50 and 70% water deficit stress, respectively. However, The response of plants to drought stress was significantly averted by application of sorghum extracts. Foliar application of sorghum extract at 2.5 and 5% on mung bean plants grown under high drought stress significantly increased yield

of plant by 50% and 45.3% over sole application of higher drought stress respectively.

Average biomass of mung bean plant was reduced up to 49.9% and 58.5% of control by 50 and 70% water deficit stress, respectively (Table 1). Also, application of sorghum extract posed significant increase in biomass of the plant.

The interaction between water deficit stress and sorghum extract treatments significantly affected dry weight accumulation of mung bean plant. Foliar application of 2.5 and 5% sorghum extract on plant grown under 50% water deficit stress increased plant biomass by 29.2% and 92.1%, respectively over sole application of 50% water deficit. However, at higher water deficit stress, application of sorghum extracts slightly improve dry weight accumulation.

##### Effect of sorghum water extracts on yield components of mung bean grown under different water deficit stresses

Average pods number of plant was significantly reduced by water deficit stress. The reduction increased from 37.8% of control in 50% water deficit to 48.2 % of control in 70% water deficit stress (Table 2). Application of sorghum extracts caused considerable increase in average number of pods. Various interaction treatments significantly affected number of pods per plant. Foliar spray of sorghum extract at 2.5 and 5% on plants grown under the aforementioned water stresses results in statistically similar number of pods (6.33, 5.90), respectively as those obtained by control treatment (6.40). Average number of seeds per pod was not significantly affected by drought stress applied on mung bean plant. On the other hand application of sorghum extracts

**Table 1-** Effect of allelopathic sorghum water extracts (E) on grain yield and plant dry weight of mung bean grown under different water stresses (D).

| Water deficit<br>(% of field capacity) | Sorghum water extracts (W / V)* |          |            |         |
|--|---------------------------------|----------|------------|---------|
|  | Control                         | 2.5%     | 5%         | Average |
| <b>Yield (t ha<sup>-1</sup>)</b>       |                                 |          |            |         |
| 50 (Control)                           | 0.598                           | 0.947    | 0.697      | 0.747   |
| 75                                     | 0.280                           | 0.394    | 0.447      | 0.374   |
| 85                                     | 0.207                           | 0.289    | 0.434      | 0.310   |
| Average                                | 0.362                           | 0.543    | 0.526      |         |
| LSD ≤ 0.05                             | D=0.269                         | E= 0.160 | D×E= 0.310 |         |
| <b>Plant dry weight (g)</b>            |                                 |          |            |         |
| 20 (Control)                           | 14.0                            | 19.8     | 25.7       | 19.8    |
| 50                                     | 8.9                             | 11.5     | 17.1       | 12.5    |
| 70                                     | 7.8                             | 9.4      | 8.9        | 8.7     |
| Average                                | 10.2                            | 13.6     | 17.2       |         |
| LSD ≤ 0.05                             | D=4.11                          | E=1.97   | D×E=4.34   |         |

\*

**Average of three replicates**

significantly enhanced average number of seeds per pod. The interaction of water deficit stress and sorghum extract treatment did not show significant interaction on number of seeds per pod.

Results presented in table 2 exhibited that application of sorghum water extract and exposed of plant to water deficit stress did not have significant impact on average weight of seeds. Also, the interaction of both treatments did not have significant impact on 100-seed weight.

**Effect of allelopathic sorghum water extracts on number of branches per plant and plant height of mung bean grown under different water stresses**

Average number of branches per plant were considerably reduced by water deficit stress and increased by application of sorghum extracts. However, such differences were not statistically significant (Table 3). Also, the interaction between water stress and sorghum extract did not show significant differences. However, at water stress level 50% and 70% of water deficit)

**Table 2-** Effect of allelopathic sorghum water extracts (E) on number of pods per mung bean plant grown under different water stresses (D).

| Water deficit<br>(% of field capacity) | Sorghum water extracts (W / V)* |        |          |         |
|--|---------------------------------|--------|----------|---------|
|  | Control                         | 2.5%   | 5%       | Average |
|  | <b>Number of pods per plant</b> |        |          |         |
| 20 (Control)                           | 6.40                            | 9.27   | 9.00     | 8.22    |
| 50                                     | 4.27                            | 6.33   | 4.73     | 5.11    |
| 70                                     | 2.80                            | 4.07   | 5.90     | 4.26    |
| Average                                | 4.49                            | 6.56   | 6.54     |         |
| LSD $\leq$ 0.05                        | D=2.291                         | E=NS   | D×E=3.56 |         |
|  | <b>Number of seeds per pod</b>  |        |          |         |
| 20 (Control)                           | 6.20                            | 7.80   | 6.50     | 6.83    |
| 50                                     | 5.40                            | 6.27   | 6.30     | 5.99    |
| 70                                     | 6.20                            | 5.90   | 5.37     | 5.82    |
| Average                                | 5.93                            | 6.66   | 6.06     |         |
| LSD $\leq$ 0.05                        | D=NS                            | E=0.04 | D×E=NS   |         |
|  | <b>Weight of 100 seeds (g)</b>  |        |          |         |
| 20 (Control)                           | 5.50                            | 5.40   | 4.73     | 5.21    |
| 50                                     | 4.80                            | 4.87   | 5.10     | 4.92    |
| 70                                     | 5.00                            | 4.70   | 4.67     | 4.79    |
| Average                                | 5.10                            | 4.99   | 4.83     |         |
| LSD $\leq$ 0.05                        | D=NS                            | E=NS   | D×E=NS   |         |

\*Average of three replicates

Application of 5% sorghum extract increased the number of branches by 45.6% and 16.2% over the treatment of sole application of 50 and 70 % water deficit respectively.

The data presented in table 3 revealed that plant height was significantly reduced by 38.4% and 57.2% over control by application of water deficit stress at 50 and 70% of field capacity, respectively. On the other hand, application of water extract at 2.5

and 5% significantly stimulated plant height by 92.4% and 20.1% over control.

The interaction between sorghum water extract and drought stress did not significantly affect plant height of mung bean. However, maximum plant height (19.77) and minimum plant height (7.80) was recorded in plants exposed control treatment with 5% sorghum extract and in plants exposed to higher water stress level alone, respectively.

**Table 3-**Effect of allelopathic sorghum water extracts (E) on number of branches per plant and plant height of mung bean grown under different water stresses (D).

| Water deficit<br>(% of field capacity) | Sorghum water extracts (W / V)* |        |                  |         |
|--|---------------------------------|--------|------------------|---------|
|  | Control                         | 2.5%   | 5%               | Average |
| <b>Number of branches per plant</b>    |                                 |        |                  |         |
| 20 (Control)                           | 3.93                            | 4.87   | 4.40             | 4.40    |
| 50                                     | 3.07                            | 3.73   | 4.47             | 3.42    |
| 70                                     | 2.87                            | 3.27   | 3.33             | 3.16    |
| Average                                | 3.29                            | 3.96   | 3.73             |         |
| LSD $\leq$ 0.05                        | D=N.S                           | E=N.S  | D $\times$ E=N.S |         |
| <b>Plant height (cm)</b>               |                                 |        |                  |         |
| 20 (Control)                           | 15.37                           | 25.67  | 19.77            | 20.27   |
| 50                                     | 8.87                            | 17.07  | 11.53            | 12.49   |
| 70                                     | 7.80                            | 8.87   | 9.37             | 8.68    |
| Average                                | 10.68                           | 17.20  | 13.56            |         |
| LSD $\leq$ 0.05                        | D=2.03                          | E=1.07 | D $\times$ E=NS  |         |

\*Average of three replicates

### Effect of allelopathic sorghum water extracts on chlorophyll and proline content of leaves of mung bean grown under different water stresses

Results presented in table 4 revealed that total chlorophyll content of leaves were not significantly influenced by sorghum water extract and water deficit stress treatments. However, the interaction of water deficit stress and sorghum water extract significantly affected chlorophyll content. Application of 5% sorghum extract on plants of control drought stress treatment increased chlorophyll content by 16.7% over plants of control treatment alone. Maximum chlorophyll content was recorded in

plant grown in control water stress and sprayed with 5%

sorghum water extract. Application of sorghum water extract and expose of mung bean plants to water deficit stress did not significantly affect average proline content of leaves (Table 4). However, the interaction of both treatments showed significant effect on proline accumulation. At higher water stress, proline accumulation increased by 30.4 over control treatment (distilled water treatment). Maximum proline accumulation was recorded in leaves of plant grown under higher drought stress level and sprayed with distilled water only.

**Table 4-** Effect of allelopathic sorghum water extracts (E) on chlorophyll content and proline content of leaves of mung bean plant grown under different water stresses (D).

| Water deficit<br>(% of field capacity)                    | Sorghum water extracts (W / V)* |       |                   |         |
|---|---------------------------------|-------|-------------------|---------|
|   | Control                         | 2.5%  | 5%                | Average |
| <b>Total chlorophyll content (mg/g fresh weight)</b>      |                                 |       |                   |         |
| 20 (Control)  | 4.83                            | 5.70  | 6.40              | 5.04    |
| 50  | 3.83                            | 4.73  | 3.70              | 4.09    |
| 70  | 3.83                            | 3.10  | 4.47              | 3.80    |
| Average   | 4.17                            | 4.51  | 4.26              |         |
| LSD $\leq$ 0.05   | D=N.S                           | E=N.S | D $\times$ E=2.33 |         |
| <b>proline content (<math>\mu</math>g/g fresh weight)</b> |                                 |       |                   |         |
| 20 (Control)  | 6.64                            | 6.73  | 6.78              | 6.72    |
| 50  | 7.04                            | 7.32  | 7.11              | 7.16    |
| 70  | 9.23                            | 8.66  | 8.69              | 8.69    |
| Average   | 7.28                            | 7.76  | 7.52              |         |
| LSD $\leq$ 0.05   | D= 2.04                         | E=N.S | D $\times$ E=2.33 |         |

\*Average of three replicates

### Discussion

Crop plants are exposed to several environmental stresses, all affecting plant growth and development, which consequently hampers the productivity of crop plants [13,14

and 15]. Drought is considered the single most devastating environmental stress, which decreases crop productivity more than any other environmental stress [16]. Drought severely affects plant growth and development

with substantial reductions in crop growth rate and biomass accumulation. There are two strategies for increase tolerance of plant to drought, the first is by develop resistance by traditional breeding program or molecular genetic engineering. The other method is avoid the stress using plant growth regulators and mycorrhizal association [3]. Recently, extract of certain plant spp prove to have supportive effect to improve drought tolerance of plant [6]. The results of the present work indicated that water deficit stress significantly reduced crop yield and biomass accumulation and the reduction increased with increased drought stress. The reduction in these parameters are coincided with the general trends of the effect of drought on plants. Several investigators indicated that drought inhibited growth by reducing rate of cell division and expansion, leaf size, stem elongation and root proliferation, and disturbing stomatal oscillations, metabolic activities, plant water and nutrient relations [5 and 17]. Analysis of data of yield components in the present revealed that the decreased in yield by drought stress was mainly due to the reduction of number of pods per plant since the other yield component parameters (100-seed weight and number of seeds per pod) were slightly affected. It is possible that pollination and / or fertilization adversely affected by drought stress and thereby inhibiting the formation of pods. Mafakheri [18] found that drought stress at anthesis phase reduced seed yield more severe than that at vegetative stage. Boyer and Westgate [19] indicated that early reproductive processes particularly those of micro and megasporogenesis, pollen and stigma viability, anthesis, pollination, pollen tube growth, fertilization, and early embryo development are all highly susceptible to drought and/or heat stress. They added that failure of any of these processes decreases fertilization or increases early embryo abortion, leading to lower number of pods, seeds or grains, thus limiting crop yield. The magnitude of drought effect is species and severity of drought dependence.

The significant reduction of plant height by drought in this study is in agreement with the general trend of the effect of drought on plant. It has been reported that drought is drastically affected cell division and cell enlargement which are the major components of growth beside differentiation [20], thus

inhibiting growth of plant. Plant height is directly linked to the productive potential of plant in terms of grain yield [21] since it represents a good storage organ (sink) for photosynthetic metabolites. Wheat genotypes with higher plant height were more tolerant than genotype with lower plant height [22].

Drought stress can also alter the tissue concentrations of chlorophylls [23]. However, there is inconsistency in the results of the investigators. some showed increasing chlorophyll content of wheat under drought stress [24 and 25], while others reported reduction in drought-stressed cotton [26], *Catharanthus roseus* [27], sunflower [28] and *Vaccinium myrtillus* [29]. In our drought-stress treatments, chlorophyll content remain statistically similar to that of control treatment. It is possible that the reduction in chlorophyll is taken place by drought stress but it couldn't be observed due to the decrease in leaf area .

Although proline was highly accumulated in plant exposed to higher water stress and sprayed with distilled water, the other treatments in which sorghum water extracts are involved did not show this trend of stimulation since no significant differences were observed among them. This suggest that the water extract might mitigate the drought stress and thus decreased the accumulation of proline. Several papers revealed that proline accumulated drastically under drought condition in several crops [3].

The increase of mung bean yield and biomass accumulation by application of sorghum extract suggests that the extract contains some phenolic acids, minerals and growth regulators which could stimulate growth of the mung bean plants. Foliar application of plant extracts was reported to improve growth of plants due to the presence of the aforementioned compounds in the extracts. Maqbool [30] found that foliar application of diluted sorghum extracts on maize under drought stress at vegetative stage manifested that low concentrations enhanced the morphological as well as biochemical attributes. In another experiment, Singh . [31] found that foliar spray of more diluted concentrations of *Nicotiana plumbaginifolia* leachate improved relative water content, enhanced nitrate reductase activity of leaves, and antioxidative defense as compared to more concentrated leachates in water stressed maize. Foliar application of *Moringa* (*Moringa*

oleifera L.) leaves extract enhanced the productivity of several arable crops such as soybean (*Glycine max*), sugarcane (*Saccharum officinarum*), corn, sorghum, black bean (*P. vulgaris*), coffee (*Coffea Arabica L.*), bell pepper (*Capsicum annuum L.*), and onion (*Allium cepa L.*). In general different cultivars behave differently in their response to moringa extract.

It has been reported that plants exposed to drought lead to elevated oxidative stress with over-production of reactive oxygen species (ROS), which are highly toxic and cause damage to proteins, lipids, carbohydrates, and DNA [32]. In this study, the improvement of seed yield and dry weight accumulation of mung bean grown under drought stress was clearly observed after foliar application of sorghum water extracts. No attempt was made to identify the chemical compounds in the extract; however Alsaadawi [33] identified several phenolic acids in sorghum extract, some of these have antioxidant properties and thus can modulate the crop growth and productivity under drought stress. Abenavoli [34] found that the increased concentration of coumarin (0, 0.1, 1, 2.5, and 5 mM) in grown medium of durum wheat under nitrate deficient conditions accelerated the nitrate translocation from roots to shoots. Likewise, Han [35] revealed that aqueous extract of rhizome, leaf, and stem of ginger (*Zingiber officinale*) enhances the drought resistance in soybean (*Glycine max*) seeds by stimulating the water uptake under drought stress condition. In a laboratory experiment, maize seeds were soaked in diluted concentrations of sorghum extract for 12 h and sown in washed sand for 7 days and submitted to drought. The emergence of seedlings decreased with increased dilutions, and the most effective dilution under control was 0.25 ml L<sup>-1</sup>, while 0.75 ml<sup>-1</sup> under drought [30]. Application of Moringa leaves extract improved grain yield of wheat due to presence of antioxidant compounds such as flavanoids, phenolic acids and ascorbic acid [36]. These compounds can enhance crop growth and productivity under drought stress.

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