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IMPACT OF DEFICIT IRRIGATION ON GROWTH AND YIELD OF TWO MASH [*VIGNA MUNGO* (L.) HEPPER] CULTIVARS

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Abstract

Water deficiency is considered one of the major limiting factors which adversely affects the growthand yield of crop. Current study was conducted to access the impacts of drought on two *Vigna mungo*cvs. (6036-21 and ES-1). A field experiment was conducted in complete randomized design with two treatments (control and drought). Drought was imposed at vegetative stage. To analyze the impact of drought stress physiological and yield attributes were recorded. Results showed thatdrought stress causes greater reduction in fresh and dry biomass (22%, 33%) and (49% and 54%), SPAD (9% and 19%) and quantum yield of PSII (21% and 31%) in both cvs. 6036-21 and ES-1 respectively. Similarly, greater reduction in yield attributes was also observed as number of pods (26% and 34%), number of seeds (6% and 12%), pod's length (5% and 9%) and 100 seeds weight (18% and 20%) in both cvs. 6036-21 and ES-1 respectively. However, plant's height (41% and 31%), number of leaves (9% and 7%), number of pods (26% and 34%) and relative water content (27% and 26%) reduced in cv. 6036-21 and ES-1 respectively. Correlation coefficient analysis represents positive correlation of droughttolerance with RWC, number of pods and quantum yield of PSII. Overall findings indicated that cv. 6036-21 exhibits less reduction in growth and yield attributes under drought stress as compared to cv. ES-1. Thus, cv. 6036-21 found to be more resistant against drought stress and could be used in further breeding program.

Key words: Biomass, Drought, Quantum yield of PSII, *Vigna mungo*, Yield,

Introduction

Absence of adequate moisture which is essential for the normal growth of plants is termed as drought (Baroowa & Gogoi, 2016). Among the abiotic stresses, drought is the dominant abiotic stress which negatively disturb the growth and yield of crop (Baroowa & Gogoi, 2012a). Global warming is the root cause of climate change due to increased level of carbon dioxide and temperature level (García-Valdecasas Ojeda *et al.*, 2021). In both agricultural and natural ecosystem, drought will decrease plant growth as well as food production. Plants have dietary importance for humans. Human starvation is directly proportional to drought stress and this situation will be worse with increase in population growth (Pradhan *et al.*, 2019). Currentpopulation is 7.9 billion while in 2050 it will be 9.7 billion (Yin & Ding, 2021). So, more efforts are required to improve existing varieties and investigate new tolerant plants.

Black gram (*Vigna mungo* L. Hepper) is significant stress-resistant, hardy and short duration legume crop. Being a legume, black gram has comparatively a short life span containing 90-120 days with improved nitrogen soil content (Nilanthi *et al.*, 2014). Black gram is widely consumed as a food crop. Additionally, it has a dynamic role in sustaining soil productiveness by adjusting the nitrogen in atmospheric (Baroowa & Gogoi, 2012a).

It was studied that mostly plants show four kinds of response mechanisms to cope against droughtstress i.e., drought tolerance, drought recovery, drought avoidance and drought escape (Fang & Xiong, 2015). The major approaches of plants against drought are drought tolerance and drought avoidance

A well-known tolerance mechanism to drought stress is the accumulation of certain osmolytes such as proline, glycine betaine etc. It acts as cellular osmotic adjustor and also defend and alleviate important components of cell such as protein, detoxify reactive oxygen species (ROS) and photosynthetic apparatus etc. (Baroowa *et al.*, 2012). To reduce water loss plant partially close stomata from transpiration at the initial stage of water shortage in order to cope with available carbon source to alter the metabolism (Reddy *et al.*, 2004; Hu & Xiong, 2014). Drought stress affects numerous physical processes connected with growth, development and economic yield of a crop (Hsiao *et al.*, 1976). Water stress interrupts normal turgor pressure. Cell enlargement may be stopped due to dropping of cell turgidity that causes reduced plant development.

Water scarcity may change the pattern of growth. Increase of shoot to root ratio, amount of lignification and cutinization, decrease of leaf index area and cell wall thickening are the major outcomes of drought frequently (Hossain *et al.*, 2010). It was found that water stress effects number of leaves and leaf area which ultimately decreased yield of plants (Kumari & Chakraborty, 2019). Baroowa *et al*, (2016) suggested that drought stress caused reduction in leaf area in mash bean which effects its yield. The objective of the current study was to investigate the impact of drought stress on growth and yield attributes of mash crop, for this purpose two mash cultivars were selected and grown in field under water deficit condition.

Materials and methods

Seeds of two *Vigna mungo* cultivars (6036-21 and ES-1) were collected from Nuclear Institute of Agriculture and Biology (NIAB) Faisalabad.

Field preparation

Area for conducting an experiment (52 × 45 feet) from Botanical Garden of The Women University Multan was selected, which is located in the North site. Firstly, field was ploughed and divided into two sections for control and drought treatments. Each section consists of two subplots. In both plots eight rows were prepared for drought and eight for control treatment of both cultivars. The experiment was carried out in CRD (completely randomized design) with replicates.

Sowing

Sowing was done manually during August, 2021. Experiment duration was about three months. Seeds were sown at 2 cm depth with spacing of 8-10 cm and 30 cm between rows. In each row almost 17-20 seeds were sown. After sowing watering was done. During experiment the average temperature was around 30-35℃ and photoperiod was10-13.5 hours.

Germination

Seeds started germinate after 10 days of sowing approximately. Watering was done every week during the start of experiment. Three weeks later, tagging was done to identify cultivars (6036-21and ES-1) easily throughout the field. Flowering at vegetative stage appeared after 30 days whilepod formation occurred almost after six weeks of sowing.

Attack of insects

At vegetative stage, weeds were removed from field manually time to time when required. Field was sprayed to reduce the attack of insects and weeds growth. Due to weather change, two times rained at vegetative stage. 1st rain was not heavy and continued just 10 minutes but 2nd rain was heavy and occurred almost 2 hours.

Drought

At the end of vegetative stage, drought stress was imposed in half of the sub plots of the field by withholding irrigation water. While watering was continued when required on the control side. At this stage, 10 plants from each plot were selected randomly for collection of data

Soil analysis

For soil analysis, sample of soil was collected from different places of field. Soil was taken around one feet depth from six different sites of the field. Soil analysis was performed from Soil and Water Testing Laboratory Multan.

Biomass

To measure the biomass, plants were uprooted. Shoot and root were separated to record their fresh weight by using electric balance. Then shoot and root were oven dried separately at 65°C to record dry weight.

Relative water content (RWC) of leaves

To calculate the RWC of leaf, mature leaves from each plant were collected and fresh weight was measured instantly. After measuring fresh weight, leaves were shifted into beaker having distilledwater for almost 4 hours to attain turgidity. After that, turgid weight was recorded after blotting surface area with tissue paper. To record dry weight these leaves were then oven dried at 70°C for2 days.

RWC was calculated by using this formula

RWC (%) = [(FW-DW) / (TW-DW)] × 100

Chlorophyll content of leaves (SPAD)

Relative leaf chlorophyll contents of the control and drought stressed plants leaves of each cultivar was recorded by using the pocket sized instrument (Minolta) SPAD-502. Measurements were taken from the mature leaves from the top of the plants.

Quantum yield of PSII

For the measurement of quantum yield of PSII the instrument FluorPen (FP-100 MX-LM, Photon System International) was used. The data was taken after 28 days of drought stress application. Young and mature leaves were selectedto obtain data at day time in sunlight. The formula used for the calculation of QY PS II

Quantum yield of PSII = Fv/Fm

Plant's height was measured by the help of ruler from the tip of plant shoot up to the end of the root. Measurements were taken in centimeters.

No. of leaves /plant

Number of leaves were counted before taking harvest from the 10 plants which were already tagged.

No. of pods /plant

At reproductive stage, total number of pods/plants were counted for each cultivar.

No. of seeds /pod

Pods were harvested and collected manually from each selected plant after maturity. Then number of seeds per pod were counted and collected.

Pod's length

After the collection of pods, length of pods was measured by using the scale. Length of pods were measured in centimeters.

100 seeds weight

100 seeds randomly selected for data from each cultivar of *Vigna mungo*. Seeds were weightedby using the electric balance.

Statistical analysis:

Graphic and tabulated values were obtained by using standard computer software program MS Excel. Arithmetic packages for example CoStat and MS EXCEL were utilized for statistically examination of the data. Two-way ANOVA was used to compare the means of both cultivars. Least significant differences at 0.05 probability level were calculated by LSD. Correlation coefficient analysis was performed by using OriginPro 2021.

RESULTS

Drought stress effects plant's productivity. To access the growth and yield attributes under water deficient conditions two cultivars of *Vigna mungo* were grown in field.

Effects of water deficiency on biomass

Results showed that water shortage dramatically affected the biomass of shoot and root in both cultivars.

A significant reduction ($P \leq 0.001$) was found in 6036-21 and ES-1 cultivars due to drought stressfor root fresh weight. Under drought treatment the average values of root fresh weight in 6036-21and ES-1 had reduced 22% and 33% respectively. A significant decrease ($P \leq 0.01$) was observedin 6036-21 and ES-1 cultivars for fresh weight of shoots due to deficient water. In this case, more reduction observed in 6036-21 plants. It was approximately 38% and 34% in 6036-21 and ES-1 respectively.

Results related to root dry weight indicated significant reduction ($P \leq 0.001$) in both cultivars of stressed plants. The cultivar 6036-21 reduced 49 % while ES-1 54%. Drought treated plants of 6036-21 indicated 46% reduction than control. While, ES-1 showed reduction 47% for stressed plants.

Chlorophyll content of leaves (SPAD)

Chlorophyll content in each cultivar of black gram was reduced due to drought stress. A significant decrease ($P \leq 0.001$) was noticed in ES-1 cultivars due to drought. In case of 6036-21 a little reduction observed while ES-1showed more reduction.

Impacts of drought on soil

Results indicated that the soil quality was medium, and was average soil for plant growth. Its pH was 8.1 that was alkaline. Plants showed efficient growth under 5-7 pH. In its composition just 0.57 %organic matter was noticed. And other available minerals were phosphorus 9 mg and potassium 2mg. These both were poor for crop growth. Soil was loamy (consist of equal parts of all three soiltypes) in texture. It is considered best soil for cultivation.

Quantum yield of PS II

Due to drought, prominent reduction was observed in both cultivars. In both cultivar of black gram(6036-21 and ES-1) a significant reduction ($p \leq 0.001$) was detected due to drought stress for quantum yield of PSII. The plants of 6036-21 which were imposed to drought indicated almost 21% reduction than control. While, ES-1 showed reduction 31% for stressed plants. Hence, due to drought ES-1 showed more reduction than 6036-21.

Plant's height (cm)

A significant reduction ($p \leq 0.01$) was observed in 6036-21 and ES-1 cultivar for drought as compared to control. Under water stress the average values of plant height in 6036-21 and ES-1 had reduced around 41% and 31% respectively. The tallest plant was around (55 cm) of 6036-21 cultivar and the shortest plant was (37 cm) of ES-1 in control conditions. While in drought condition tallest plant was 33cm and shortest was 25cm in cv. 6036-21 and ES-1 respectively.

Effects of drought on relative water content

Results related to relative water content indicated significant reduction ($P \leq 0.001$) in both cultivarsof stressed plants. ES-1 cultivars had 26% reduction in RWC and 27% in 6036-21.

Number of leaves

A significant reduction ($p \leq 0.01$) was noticed in 6036-21 and ES-1 cultivar drought as compared to control. The plants of 6036-21 which were imposed to drought indicated almost 9 % reductionthan control. While, ES-1 showed less reduction 7% for stressed plants. The highest number of leaves in ES-1 cultivars was 75 and 62 for control and drought treated plants respectively.

Number of Pods/plants

A significant reduction ($p \leq 0.001$) was observed in 6036-21 and ES-1cultivar drought as compared to control. Approximately 26% reduction was recorded in 6036-21 and in ES-1 it was 34%. Therefore, it was clearly observed that ES-1 showed more reduction. The maximum number of pods was around 48/plant in 6036-21 and 32/plant in ES-1 respectively in non-stressed plants. While in experimental treatment highest number 34 found in cv. 6036-21 and in case of ES-1 it was 28. On the other hand, drought-imposed plants showed 20 and 15 number of pods per plant (6036-21 and ES-1) correspondingly.

Number of seeds/pods

Drought stress effects the quantity of seeds in each cultivar. Due to drought, prominent reduction was observed in both cultivars. Under drought treatment the average values of seeds showed that ES-1 and 6036-21 had around 12% and 6% reduction respectively. The highest number of seeds was found in 6036-21 cultivar. Overall minor variation was observed between both cultivars.

Pods length (cm)

The reduction in length of pods was 5% and 9% in the cultivars 6036-21 and ES-1 respectively. Lengthy pods were found in 6036-21 cultivar which were approximately 5.1 cm.

100 seeds weight (g)

A significant reduction ($p \leq 0.01$) was observed in 6036-21 and ES-1cultivar for drought as compared to control. The plants of 6036-21 which were imposed to drought indicated almost 18%reduction than untreated plants. While, ES-1 showed more reduction just 20% for stressed plants.

Discussion

Drought stress affects numerous physiological processes connected with growth, development and economic yield of a crop. Between the abiotic stresses, drought is the most important stress factor which effects the yield and growth of crop. Drought stress mainly effects the soil water status andits porosity which indirectly had impacts on crop. Drought stress declined the moisture content ofsoil as compared to normal range. Siebert *et al*, (2019) reported that in ecosystem the vital processes as decaying of organic compounds, fertility of soil and nutrients cycle effects badly in future due to change in weather patterns.

In present study, a field experiment was conducted with mash crop to access the impacts of drought on growth andyield attributes. Drought stress reduced the fresh and dry biomass of crops as documented in maize (Efeoğlu *et al.,* 2009), in mung bean (Kumari & Chakraborty, 2019), in sesame (García-Caparrós *et al.,* 2019). The decrease in fresh and dry biomass of *V. mungo* cultivars was directly associated with water status. During vegetative stage, drought stress induced the reduction of plant height, lower water status and leaf senescence which caused the reduction of shoot weight (Shao *et al.*, 2008). Greco & Cavagnaro (2003) reported that water deficiencyinfluences the ratio of root/shoot biomass in *Trichloris pluriflora*. The drought caused decrease inbiomass had earlier been reported in *Sorghum bicolor* (L.) Moench, *Triticum aestivum L., Zea mays* L., and *Helianthus annuus* L.

Results of present study also suggested the drought caused the same reduction impact on biomass in both cultivars of black gram under field conditions. In current study, drought stress induced the reduction relative water content of black gram cultivars. Reduced values of relative water content demonstrated that the severe water stress affected the physiological activity of plant, which could also affect the plant photosynthetic rate. Various studies such as by Ocampo & Robles (2000) find out that drought stress induced reduction in relative water content of plants due to decreased transpiration rate and a smaller number of leaves.Similar results were also found by Hossain *et al.* (2010) while working on mung bean. According to various studies the relative water content showed reduction at different stages especially at vegetative stage. However, worse effects were recorded at reproductive stage. Similar result was observed in the experiment on mung bean crop Bano *et al.* (2021) and on *Vigna radiata* by Habibzadeh *et al.* (2015).

Numerous studies stated that drought stress decrease chlorophyll content in leaves of plants. Gurumurthy *et al.* (2019) observed reduction in chlorophyll content due to water stress in mash bean plants. Various studies suggested that water deficit induced reduction in chlorophyll contentwhich results to loss of chloroplast membranes, extreme swelling, alteration of the lamellae vesiculation, and the appearance of lipid precipitations (Baroowa & Gogoi, 2012b). In response to water deficit conditions chlorophyll lost in plants which occurs in the mesophyll cells with a lesseramount (Anjum *et al.*, 2011). Current study also observed the same response of chlorophyll contentin both cultivar of black gram that was decreased due to drought stress. Similar results were found by the Batra *et al.* (2014). Chlorophyll content of all the studied cultivars is severely affectedunder drought stress by alteration of the chlorophyll content, changes in photosynthetic components and there by damaging the photosynthetic apparatus. Li *et al.* (2013) also finds out same trends while working with sugar beet plant and suggested that slight reduction in drought tolerant plant was observed.

In both cultivar of black gram (6036-21 and ES-1) a significant reduction was noticed due to drought stress for quantum yield of PSII. Similar findings are also attained by Chen with maize plants (Chen *et al.*, 2022). Lu & Zhang (1999) also found that quantum yield of PSII reduced due to drought stress. In response to the drought stress, both cultivars showed decrease in QY of PSII, which indicated that a high proportion of the PSII reaction centers remained closed, which inturn indicates that the balance among excitation rate and electron transfer rate had altered. Isoda (2010) worked with two varieties (peanuts and cotton) and reported that peanuts showed more worse impact of drought stress as compared to cotton which was resistant against drought stress (Isoda, 2010). Similar responses were obtained by Lu & Zhang, (1999) with wheat crop.

Sucu *et al.* (2018) reported that water deficiency is considered the major limiting factor for sustainable agriculture in reduction of crop yield by 1–30%. Under drought stress plant height in both cultivars had reduced which might be due to reduced cell turgor which decreased the rate of cell division and cell expansion as these are the process of cell growth and development (Baroowa *et al.,* 2016). Similar results were obtained by (Kumari & Chakraborty, 2019) with mung bean and(Sibomana *et al.,* 2013) with tomatoes.

Among the various yield attributes studied in current work, number of pods decreased in both cultivars under drought stress. Reduction is connected to interruption of leaf gas exchange properties which not only reduce the size of the source and sinks tissues but the phloem loading assimilates translocation and dry matter partitioning (Anjum *et al.*, 2011). Identical results were attained by Mondal while working on *Vigna radiata* (Mondal *et al.*, 2011) and by Nielsen in wheat(Nielsen & Nelson, 1998; Nilanthi *et al.*, 2014).

Drought stress effects the number of leaves of plant. It was reported that due to termination of new leaf production and with increased leaf abscission the number of leaves reduced studied by Pandey & Chakraborty (2016). This higher leaf abscission may be linked with water stress which inducedproduction of more ethylene (Baroowa *et al.*, 2016). The decrease in plant leaf number might be due to the inhibition of mitosis, and newer cell formation documented by Bharadwaj (2018). The drought stressed plants of 6036-21 indicated higher reduction for number of leaves than ES-1. Similar response was noticed by Kumari & Chakraborty (2019) with mung bean and by Pandey &Chakraborty (2016) on the same plant.

Drought stress effects the number of seeds in various crops. Due to drought, reduction was observed in both cultivars of *V. mungo*. Similar trend was found out in dry bean *Phaseolus vulgaris* by Gallegos & Shibata (1989) and by Hossain *et al.* (2010). They noticed that number of seeds/plant reduced due to water stress. The weight of seeds reduced in black gram plants because podsattained maturity earlier due to drought stress as compared to control plants. Water stress reduced pod formation, increased flower shedding and decreased grain yield in field (Ahmadi & Bahrani, 2009). Hu and his colleagues find out same results while doing research on soybean crop (Hu & Wiatrak, 2012).

Conclusions

Research was conducted to access the effects of drought stress on *Vigna mungo* cultivars (6036-21 and ES-1) at vegetative stage. In present study, drought stress affects the mineral nutrient relationship of soil which indirectly effects growth and yield. Results showed that due to droughtstress greater reduction in physiological parameters like fresh and dry biomass, SPAD and quantum yield of PSII was detected in ES-1 as compared to 6036-21. Similarly yield attributes such as number of pods, number of seeds, pod's length and 100 seeds weight also decreased in ES-1 cultivar. However, some other attributes as plant's height, number of leaves, number of podsand RWC represented significant reduction in 6036-21 than ES-1 cultivars. Correlation coefficient analysis gave positive correlation of drought tolerance with RWC, number of pods and quantum yield of PSII. Overall findings indicated that 6036-21 displays less reduction in growth and yield attributes as compared to ES-1 under drought conditions when grown in field.

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Table 1: Analysis of variance for the data of number of fresh and dry biomass, 100 seeds wt., RWC, SPAD, QY of PSII, plant height, No. of leaves, No. of pods, No. of seeds and pods length of two cultivars (6036-21 and ES-1) of black gram when four weeks old plantswere subjected to drought stress grown under field conditions

Source of variance	**df**	**SFW**	**SDW**	**RFW**	**RDW**	**RWC**
Drought	1	4.855**	3.138**	0.032*	1.802***	1263.86***
Cultivars	1	4.372**	0.073ns	0.104***	0.024ns	17.149ns
Drought × cultivars	1	0.363ns	0.004ns	9.633ns	0.002ns	17.149ns
Error	8	0.210	0.273	0.003	0.058	11.587
Source of variance	**df**	**SPAD**	**QY of PSII**	**plant height**	**100 seeds wt.**	
Drought	1	168.00***	0.103***	901.333***	1.386**	
Cultivars	1	29.767*	0.004ns	161.333**	0.942*	
Drought × cultivars	1	19.00ns	0.002ns	65.333*	0.003ns	
Error	8	4.467	0.001	8.5	0.088	
Source of variance	**df**	**No. of leaves**	**No. of pods**	**No. of seeds**	**pods length**	
Drought	1	152.1ns	1071.225***	2.025ns	0.576ns	
Cultivars	1	2822.4**	81.225ns	0.025ns	1.521ns	
Drought × cultivars	1	0.4ns	13.225ns	0.225 ns	0.036ns	
Error	36	264.63	55.114	1.95833	0.446	
Total	39					

ns = non-significant; *, **, * significant at 0.05, 0.01 and 0.001 probability levels, respectively**

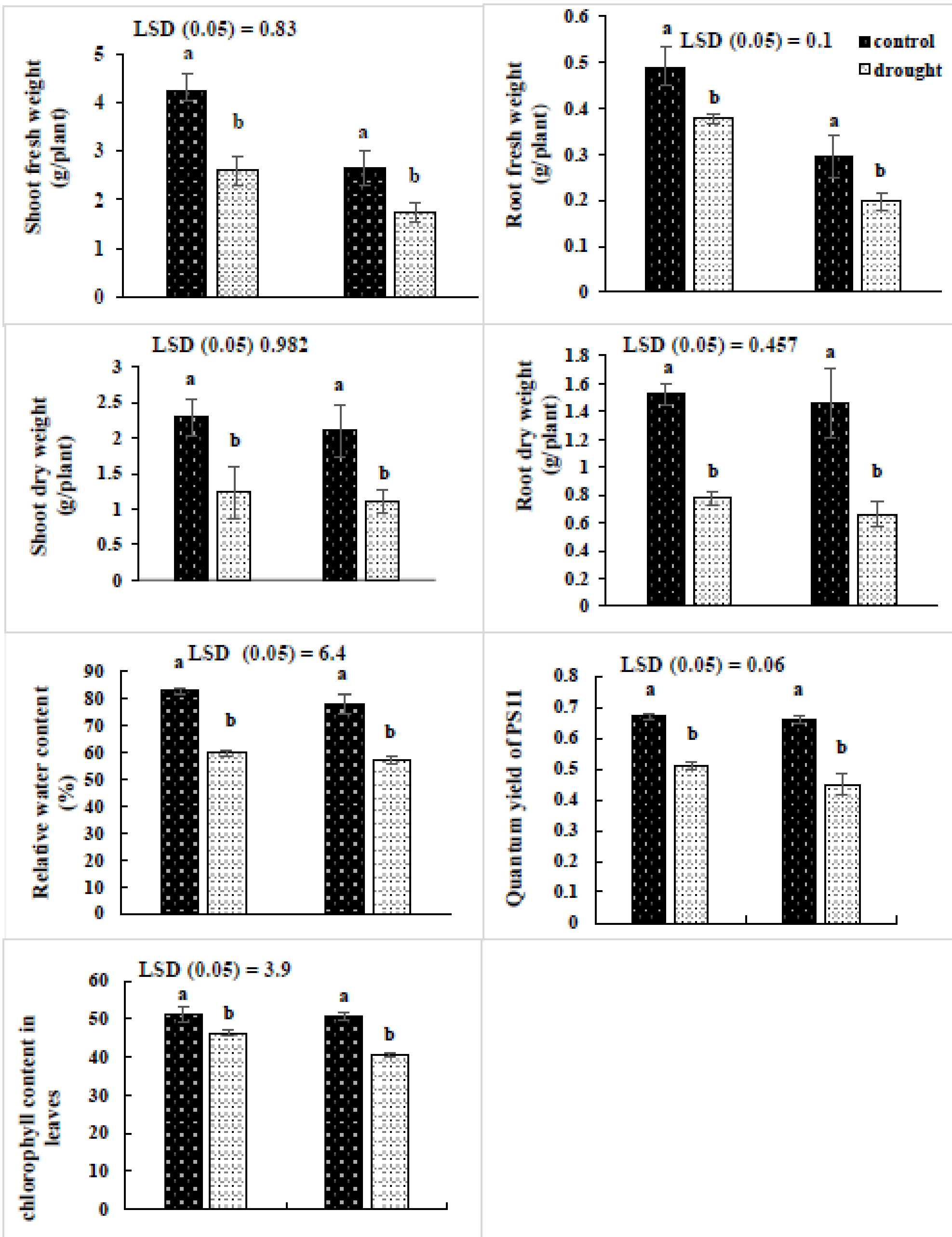

Figure 1. Shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, relative water content, quatum yield of PSII, SPAD of two cultivars (6036-21 and ES-1) of *Vigna mungo* when four weeks old plants were subjected to drought stress. The letter (a, b) showed the significant difference between mean values of both cultivars' treatments.

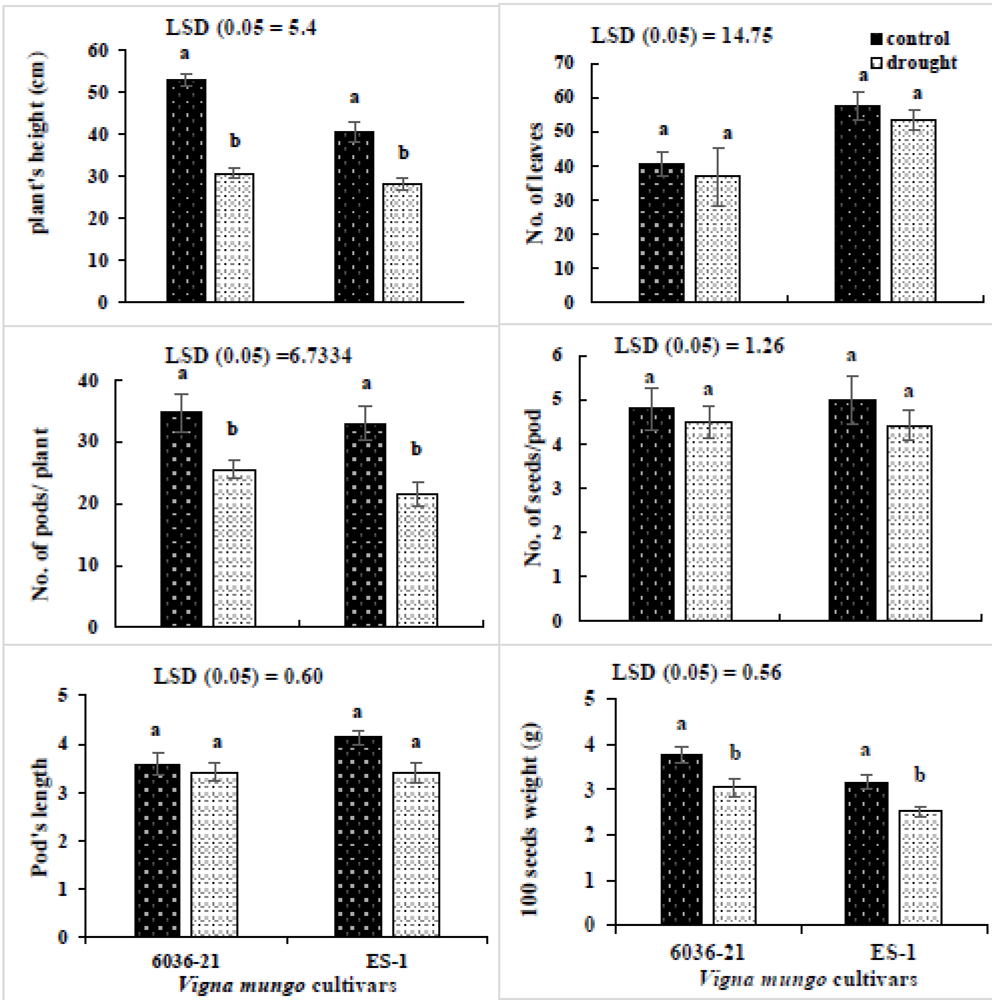

Figure 2. Plant height, No. of leaves, No. of pods/plant, No. of seed/pod, Pod's length and 100 seeds weight of two cultivars (6036-21 and ES-1) of *Vigna mungo* when four weeks old plants were subjected to drought stress. The letter (a, b) showed the significant difference between mean values of both cultivars' treatments.

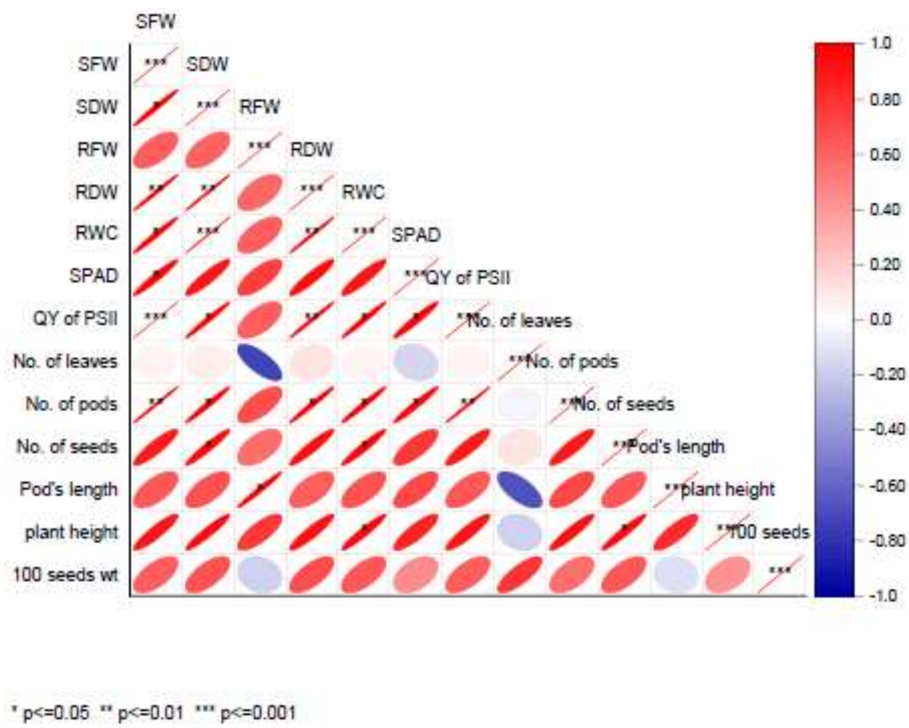

Figure 3: Correlation Coefficient analysis of physiological growth and yield attributes of both cultivars (6036-21 and ES-1) of Vigna mungo when four weeks old plants were subjected to drought stress