NPK partitioning, growth, yield and proximate composition of okra (*Abelmoschus esculentus*) under water deficit stress

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Abstract

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This experiment was conducted to determine the effects of drought stress on growth yield, NPK partitioning and nutritional composition of okra. To achieve this objective, four levels of water deficit stress (daily (control), a day interval, two days interval and three days interval irrigation) were tested on 17Lucky19 (hybrid) okra variety in a pot experiment. The experiment was laid out randomized complete block design (RCBD) with three replications. Parameters used to determine the effects of

water deficit stress were nitrogen, phosphorus and potassium contents of stems and leaves. Plant height, number of branches, number of leave, number of fruits, fresh fruit mass, dry straw mass, chlorophyll content, and proximate parameters (crude fat, crude fibre, crude protein and ash contents of the leaves) were also used. It was found that all the growth and yield parameters tested reduced with increase in water deficit levels. Similarly, all proximate parameters decreased with increase in water deficit levels with the exception of crude fibre which increased with increase in water deficit levels. In the same vein, nitrogen and potassium levels decreased with increase in water deficit levels in both leaves and stems. However, phosphorus levels in stems and leaves decreased with increase in water deficit levels. It is, therefore, concluded that 17Lucky19 is susceptible to water deficit stress. This implies that water deficit tolerant or resistant varieties should be used instead of 17Lucky19 whenever areas with irregular rainfall are to be used for cultivating this variety of okra.

Key words: Water deficit stress, okra, NPK partitioning, nutritional qualities, growth and yield

Introduction

One of the major banes to crop production is water deficit or drought stress. Drought stress negatively affects growth, yield, membrane integrity, pigment content, osmotic adjustment, water relations and photosynthetic activity of crops (Praba et al., 2009). Susceptibility of plants to drought stress varies depending degree of stress, factors affecting stress, species of plant and stages of development (Demirevska et al., 2009). Influence of drought involves impairment of seed germination process and poor stand establishment (Harris et al., 2002). Furthermore, drought leads to inhibition of cell elongation in higher plants as a result of interruption of water flow from xylem to surrounding elongating cells (Nonami, 1998). In the same, drought stress causes impairment in mitotic division, cell expansion and elongation with consequential reduction in growth and yield attributes (Hussain et al., 2008). This could be attributed to disruption of leaf gas exchange properties which not only limited the size of the source and sink tissues but also physiological processes like phloem loading, assimilate translocation and dry matter partitioning (Farooq et al., 2009). Drought stress is also responsible for reduction in size, number and longevity of leaves as a result of decrease in soil water potential (Anjum et al., 2011b). The reduction in leaf area or size by drought is attributed to suppression of leaf expansion through photosynthesis reduction (Rucker et al., 1995). Drought stress can also lead to reduction in fresh and dry biomass production in crops (Zhao et al., 2006) which is attributed to inhibition of leaf expansion, leaf development and consequently reduced light interception (Nam et al., 1998). Moreover, drought stress noticeably decreases plant height, stem diameter and leaf area in maize (Khan et al., 2001) and other crops. Occurrence of drought at flowering could result in barrenness in most cases. This could have resulted from reduction in assimilate flux to the developing ear below the threshold level required to sustain optimal grain growth (Yadav et al., 2004). For instance, exposure of maize to drought stress at tasseling stage led to significant reduction in yield and yield components (kernel rows per cob, kernel number per row, 100-kernel mass, number of kernels per cob, grain yield per plant, biological yield per plant and harvest index) (Anjum et al., 2011a). This effect could be linked to stomatal closure in response to low soil water content which decreased the intake of carbon dioxide and consequential photosynthetic activities (Flexas et al., 2004).

Decrease in chlorophyll content under drought stress is considered a typical symptom of oxidative stress which might have resulted from pigment

photo-oxidation and chlorophyll degradation (Anjum et al., 2011b). Soil dehydration (drought stress) results in decrease in chlorophyll level in form of chlorophyll a and b (Farooq et al., 2009). For instance, drought stress caused significant decrease in chlorophyll a, b and total chlorophyll contents in different sunflower varieties (Manivannan et al., 2007). Also, exposure of two olive cultivars to reduced irrigation led to lower Chlorophyll a and b contents (Guerfel et al., 2009). Water deficit-induced reduction in chlorophyll content has been ascribed to loss of chloroplast membranes, excessive swelling, distortion of the lamellae vesiculation and appearance of lipid droplets (Kaiser et al., 1981). It should be noted that decrease or unchanged levels of chlorophyll due to drought stress is dependent on duration and severity of drought stress (Zhang & Kirkham, 1996). Loss of chlorophyll contents under water stress is considered a main cause of inactivation of photosynthesis.

Chemical composition (proximate contents) has been established to be affected by drought stress (Gu et al., 2008). For instance, total carbohydrate content of plants is reduced by drought stress (Parida et al., 2007). This reduction could be attributed to reduction in photosynthetic activities with consequential reduction in photosynthate production (Stewart et al., 2007). Similar to the effect of drought stress on carbohydrate content, drought stress reduces moisture (Kallida et al., 2008), ash (Oziurk & Aydin, 2004), crude protein (Parida et al., 2007) and crude fat (Martins-Junior et al., 2008) contents of plants. However, drought stress leads to increase in plants' soluble sugar (Tawfik, 2008). Similar to soluble sugar contents, drought stress leads to increase in ash (Essafi et al., 2006), protein (Sumithra et al., 2007) and crude fibre (Sodeinde et al., 2007) contents in plants.
Drought can depress plant growth by reducing N and P uptake, transport and redistri-bution (Rouphael et al., 2012). A majority of studies have indicated that plants decrease N and P uptake with a decline in soil moisture (Sardans & Penuelas, 2012). Drought can depress plant growth by reducing N and P uptake, transport and redistribution (Rouphael et al., 2012). A majority of studies have indicated that plants decrease N and P uptake with a decline in soil moisture (Sardans & Penuelas, 2012). Drought can depress plant growth by reducing N and P uptake, transport and redistri-bution (Rouphael et al., 2012). A majority of studies have indicated that plants decrease N and P uptake with a decline in soil moisture (Sardans & Penuelas, 2012). Drought can depress plant growth by reducing N and P uptake, transport and re-distribution (Rouphael et al., 2012). Decrease N and P uptake by plants during moisture stress has been found in majority of studies (Sardans & Pe~nuelas, 2012). Drought stress can reduce plant nutrient uptake by reducing nutrient supply through mineralization (Sanaullah et al., 2012), reduction in nutrient diffusion and mass flow in the soil (Lambers et al. ,2008).

Crop yield loss through water deficit (drought) stress is too enormous for farmers of any category in crop production to bear. Therefore, crops to be produced in water deficient soils should be tested for their tolerance of the stressful environmental condition before being produced on a large scale. To achieve this objective, this research was conducted to determine the effect of water deficit stress on growth, yield and NPK partitioning and nutritional qualities of okra.

Materials and Methods

Experimental site

The experiment was carried out at the pavilion of the Agronomy Department of the University of Ilorin, Ilorin, Kwara State. The university was located on latitude 8o29'N and Longitude 4o35'E in the southern Guinea savanna Agro ecology of Nigeria

Experimental units and design

A total of sixteen experimental units (pots) were used in the experiment. Each pot was filled with 6kg of soil and the pots were perforated at the base to allow for drainage of gravitational water and prevent water logging at the instance of irrigation. The experiment was laid out in randomized complete block design (RCBD) with four replications.

Planting, treatment application and cultural

practices

Four seeds of 17Lucky19 variety of okra were planted in each pot and the resulting seedlings were later thinned to two per pot. There was daily irrigation in all the pots for five weeks after which imposition of water deficit treatments were embarked on. The treatments used were control (daily irrigation), irrigation at a day interval, irrigation at 2 days interval and irrigation at 3 days interval. The treatments lasted for two weeks after which normal irrigation (like that of the control pots) was resumed. Weed control was by hand pulling and it was done as required from the beginning to the end of the experiment to keep the plants free of weeds and avoid interspecific competition.

Data collection

Data were collected on plant height, number of branches, number of leaves, dry straw mass, number of fruits per pot and fruit fresh mass. Amounts of nitrogen, phosphorus, potassium, crude fat, crude protein, crude fibre, ash and chlorophyll present in targeted plant parts were determined as follows:

Nitrogen determination

Total nitrogen was determined by using the Kjeldal method as described by Bremmer and Mulvaney (1982). One gram each of leaf and stem samples was weighed into 250 ml conical flask. Then, 3.2 g of Kjeldahl catalyst and 100 ml of concentrated H_2SO_4 were added to the samples and heated for 30 minutes until a clear digest was got. The digest was distilled with 40% NaOH and collected in 10 ml of 2% boric acid. The distillate was titrated against 0.1N sulphuric acid till green to pink colour was observed. Total nitrogen was then calculated using equation 1.

$$\% N = \frac{(\text{Titre value} \times 0.01 \times 0.014 \times 100 \times 100)}{(\text{Weight of sample} \times 5)} \quad (1)$$

Phosphorus determination

One gram of plant sample was weighed into 20ml of acid mixture and then boiled for 10 minutes to digest. The digest was then cooled down and filtered. Phosphorus content of the filtrate was then determined using spectrophotometer.

Potassium determination

One gram of plant sample was weighed into 20ml of acid mixture and then boiled for 10 minutes to digest. The digest was cooled down and filtered. Potassium content of the filtrate was then determined using flame photometer. Amount of potassium was calculated using equation 2.

$$\text{Amount of Potassium} = \frac{((a - b) \text{ X V X F X } 100)}{(1000 \text{ X W x } 1000)} \quad (2)$$

Determination of total chlorophyll

Leaf chlorophyll content was determined by homogenizing 1g of fresh leaf samples in 15ml of ethanol. The mixture was then filtered and the filtrate was covered with aluminum foil to prevent it from being broken down by sunlight. The concentration of chlorophyll was then measured as a function of intensity of absorbed light in a spectrophotometer. Absorbance at 647 and 664 nm wavelengths was measured with UV spectrophotometer. Total and actual chlorophyll were calculated using the following formulae:

Chlorophyll a = $(13.19 \times A_{664})-(2.57 \times A_{647})$,
Chlorophyll b = $(22.1 \times A_{647})-(5.26 \times A_{664})$
Total chlorophyll = Chlorophyll a + chlorophyll b

A_{664} and A_{647} are absorbance at wavelengths 647 and 664 nm respectively

Determination of proximate composition of okra

Preparation of sample for proximate analysis Dried samples of leaves were ground into fine powder. From the ground samples, crude fat, crude protein, crude fibre and ash contents were determined using the methods described by Kirk and Sawyer (1980), AOAC (1990) and James (1995).

Crude Protein Determination

This was done using Kjeldahl method described by Chang (2003). In this method, total nitrogen was determined and multiplied by 6.25 to obtain crude protein content of plant samples. 0.5 g of each plant sample was mixed with 10ml of H_2SO_4 in a digestion flask. A tablet of selenium was then added to the mixture and the resulting

mixture was heated under a fume cupboard until the mixture turned to a clear solution (sample digest). The digest was made up to 100 ml using distilled water and kept in a volumetric flask. 10 ml of the digest was mixed with equal volume (10 ml) of 45% sodium hydroxide solution of Kjeldahl distillation apparatus. The mixture was distilled into 10 ml of 40% boric acid containing three drops of mixed indicators (bromocresol green and methyl red). A total of 50 ml distillate was collected and titrated against 0.02N EDTA until the colour turned from green to deep red (the end point). Reagent without plant sample (blank) was also distilled and titrated. The nitrogen and crude protein contents were then calculated using equation 3 and 4.

$$\%\text{Nitrogen} = \frac{(100 \times N \times 14 \times Vt)}{(W \times 1000 \times Va)} \times T \times B \qquad (3)$$

$$\%\text{Crude Protein} = \%N \times 6.25 \qquad (4)$$

W= Mass of sample (0.5 g)
N= Normality of titrant (0.02N H_2SO_4)
Vt= Total digest volume (100 ml)
Va= Volume of analyzed digest (10 ml)
T= Sample titre value
B=Blank titre value
Note: 1 ml of 1N H_2SO_4 =14 mg

Determination of crude fat

The determination was through gravimetric method described by Krick and Sawyer (1980). 5 g of plant sample was wrapped in a porous paper (whatman filter paper) and put in a thimble. The thimble was put in a soxlet reflux flask and mounted on weighed extraction flask (W_1) containing 200 ml of petroleum ether. The upper part of the reflux flask was connected to a water condenser. The solvent (petroleum ether) was heated to boil, vapourize and condense into soxlet reflux flask. Through this process the sample in the thimble was shortly covered with the solvent after it was put there until soxlet reflux flask was filled and then siphoned. The oil extract was carried down to the boiling flask. This process was allowed to go on repeatedly for four hours before the defatted sample was removed. The solvent was recovered and the oil extract was left in the flask. The flask containing the oil extract was dried in an oven at 60° C for 30 minutes to remove any remove any residual solvent. The flask was then cooled in a desiccator and weighed (W_2). The mass of oil (fat) extract was determined using equation 5.

$$\%\text{Fat} = \frac{(W_2 - W_1)}{(\text{Mass of plant sample})} \times 100 \qquad (5)$$

Where:
W_1=Mass of empty extraction flask
W_2=Mass of flask + Oil (fat) extract

Determination of Total Ash Content

This was determined through furnace incineration gravimetric as described by James (1995) and AOAC (1984). 5.0 g of prepared plant sample was weighed into a porcelain crucible of mass W_1. The sample was burnt to ashes at 550° C in a muffle furnace. After it has completely burnt into ashes, it was cooled in a desiccator and the mass of the crucible and ash was determined and recorded as W_2. Percentage of ash in the sample was determined using equation 6.

$$\%\text{Ash} = \frac{(W_2 - W_1)}{(\text{Mass of plant sample})} \times 100 \qquad (6)$$

Where:
W_1=Mass of empty extraction flask
W_2=Mass of crucible + Ash

Determination of crude fibre

This was determined by the procedure described by James (1995). 5.0 g of the prepared plant sample was weighed and boiled in 150ml of 1.25% H_2SO_4 solution for 30minutes under reflux. The boiled sample was washed in several portions of hot water using a two-fold cloth to trap plant particles. The sample was returned to the flask and boiled again in 150 ml of 1.25% sodium hydroxide for 30 minutes under the same condition. After the sample was washed in several portions of hot water, the sample was allowed to drain and dry before being transferred into a

weighed crucible where it was dried to a constant mass at 105° C using an oven. The mass of crucible + the dry sample was recorded as W_2. The dried sample was then transferred into a muffle furnace and burned into ashes. Percentage of crude fibre was determined using equation 7.

$$\%\text{Crude Fibre} = \frac{(W_2 - W_3)}{(\text{Mass of plant sample})} \times 100 \qquad (7)$$

Where:
W_2=Mass of crucible + sample after washing, boiling and drying
W_3=Mass of crucible + Sample of ash

Statistical analysis

All the data collected were subjected to analysis of variance (ANOVA) and significant means were separated using least significant difference (LSD) at 5% probability level.

Results and Discussion

Effect of water deficit on plant height and number of branches

Effect of drought stress on okra height

Height of okra plants decreased with increase in water deficit. The tallest plants were from the control plants while the shortest plants were from plants irrigated at three days interval (Table 1).

Effect of drought stress on number of branches of okra

Number of branches produced by okra plants decreased with increase in water deficit. The highest number of branches was from control plants while the lowest number of branches was from plants irrigated at three days interval (Table 1).

Effect of drought stress on number of leaves of okra

Number of leaves produced decreased with increase in water deficit. The highest number of leaves was from control plants while the lowest number of leaves was from plants irrigated at three days interval (Table 2).

Effect of drought stress on number of okra fruits

Similarly, number of fruits decreased with increase in water deficit. The highest number of fruits was from control plants while the lowest number of fruits was from plants irrigated at three days interval (Table 2).

Fruit fresh mass and dry straw mass

Effect of drought stress on okra fruit fresh mass

Mass of fresh fruits decreased with increase in water deficit. The heaviest fruits were from control plants while the lightest fruits were from plants irrigated at three days interval (Table 3).

Effect of drought stress on okra dry matter production

In the same, dry straw mass decreased with increase in water deficit though the straw mass of plants irrigated at two days interval was more than that of plants irrigated at a day interval. The heaviest straw was from control plants followed by plants irrigated at two days interval while the lightest straw was from plants irrigated at three days interval (Table 3).

Crude fat, crude fibre and crude protein

Effect of drought stress on crude fat content of okra leaves

Crude fat content decreased with increase in water deficit. The highest crude fat content was from the control plants while the lowest content of crude fat was from plants irrigated at three days interval (Fig.1).

Effect of drought stress on crude fibre content of okra leaves

Crude fibre content increased with increase water deficit. The highest crude fibre content was from plants irrigated at a day interval while the lowest content was from the control plants (Fig. 2).

Effect of drought stress on crude protein content of okra leaves

Crude protein content decreased with increase in water deficit. The highest crude protein conten was from the control plants while the lowest content of crude protein was from plants irrigated at three days interval (Fig. 3).

Chlorophyll content and Ash content

Effect of drought stress on chlorophyll content of okra leaves

Chlorophyll content decreased with increase in water deficit. The highest chlorophyll content

was from control plants while the lowest content was from plants irrigated at three days interval (Fig. 4).

Effect of drought stress on ash content of okra leaves

Ash content decreased with increase in water deficit. The highest Ash content was from control plants while the lowest content was from plants irrigated at three days interval (Fig. 5).

Effect of drought stress on nitrogen contents of okra stems and leaves

Leaf and stem nitrogen decreased with increase in water deficit. The highest leaf and stem nitrogen content was from the control plants while the lowest nitrogen content in both leaf and stem was from plants irrigated at three days interval (Fig. 6 and 7).

Effect of drought stress on leaf potassium content of okra

Leaf and stem potassium decreased with increase in water deficit. The highest leaf and stem potassium content was from the control plants while the lowest potassium content in both leaf and stem was from plants irrigated at three days interval (Fig.8 and 9).

Stem phosphorus content was highest in plants irrigated at three days interval followed by control plants while the lowest phosphorus content was from plants irrigated at a day interval. The phosphorus content of the control was higher than that of plants with water with the exception of those irrigated three days interval. The highest leaf phosphorus content was from plants irrigated at two days interval followed by control plants while the lowest phosphorus content was from plants irrigated at a day interval like that of stem phosphorus. The phosphorus content of the control was higher than that of plants with water with the exception of those irrigated two days interval (Fig. 10 and 11).

Discussion

Decrease in height as water deficit increased showed clearly that the plants were adversely affected by water deficit condition. The study of Hussein et al., (2011) and Onwugbuta-Enyi (1996) also found reduction of plant height with increase in water deficit or drought levels. Reduction in height could be linked to alteration of water potential, increase in ion toxicity, obstruction of cell division and expansion as well as ion imbalance (Arshi et al., 2005). Moreover, height reduction could be the result of inhibition of apical growth and endogenous hormonal imbalance caused by water deficit stress (Younis et al., 2010). It might equally be the result of inability of getting sufficient water and nutrient needed for cell elongation and enlargement as a result of physical dryness experienced by the plants. This might have had consequential effect on photosynthate production because water and some nutrients like potassium and chlorine are needed for successful photosynthetic activities. With less photosynthate production, translocation to the growing areas becomes a great difficulty and, therefore, growth is checked. This was manifested in reduced plant height found in this work. Moreover, water deficit might have disturbed the potential of roots to extract water and that resulted in inhibition of many physiological and biochemical processes like as nutrient uptake and assimilation (Hasegawa et al., 2000; Munns, 2002). Decrease in height might be because decrease in meristematic activities caused by water deficit because meristematic cells at the apices are responsible for increase in plant height. Furthermore, it could be attributed to lower physiological activities of the plants during morphogenesis caused by water deficit.

The desirability of having tall plants is hinged on avoidance of intra- or inter-species shading which might make a plant prone to etiolation and reduction in photosynthetic efficiency when light harvesting apparatus receive solar energy below the threshold for efficient production of photo-assimilates. Furthermore, plant height and the angle of inclination of the leaves are major factors affecting light interception by plants. Nevertheless, excessive height could make a plant prone to lodging and reduction in number of branches believed to have been caused by height gain. The consequences of excessive height constitute limitations to plant productivity because higher number of branches is a pre-requisite to having higher

number of flowers and consequently fruits. This in turn is a very important yield determinant and, therefore, it becomes a target trait for all agronomic, physiological and genetic manipulations.

High number of branches show vegetative growth success in non-grass plants and are equivalent of tillers in grasses. They can predict plant biomass yield. To some extent, economic yield can also be predicted by them. This is because the number of branches determines the number of leaves to be produced and the number of leaves produced determines the amount of photosynthate that will be produced. Therefore, if photosynthate produced is judiciously partitioned, economic yield will increase. There was reduction in the number of branches produced under water deficit condition in this work. This was equally observed by Saeed et al., (2003) when they subjected okra varieties (Parbhani Karanti and DLPG) to drought stress. Along with reduction in number of branches, they equally found reduction in fresh fruit yield per okra plant as the severity of drought stress increases. Furthermore, Zhang et al., (2011) recorded reduction in number of branches when they subjected soybean plants to moderate water stress. These results might be because of the fact that plants were not able to produce enough assimilates as a result of inhibited photosynthesis under water stress. It could also be attributed to inhibition of cell division and enlargement of meristematic tissue as well as having less amount of water uptake to prepare sufficient food needed for growth (Zubarer et al., 2007).

There was an inverse relationship between water deficit and number of leaves produced. This implies that increase in water deficit led to decrease in number of leaves produced. In the same vein, Wullschleger et al., (2005) and Manivannan et al., (2008) found that water stress mostly decreased leaf growth and leaf areas in okra crop and sunflower respectively. This might be because plants faced with the problem of water deficit experienced a change in cell wall properties and photosynthetic rates which then led to reduction in number of leaves produced. Furthermore, reduction in number of leaves could have resulted from reduced turgor or reduction in extensibility of cell walls (Neumann, 1993). The problem might equally be due to water stress in the short run and ion toxicity in the long run (Yeo et al., 1991). This reduction in number of leaves can be seen as an avoidance mechanism which occurs so as to reduce water loss by transpiration. This reduction in water loss by transpiration is also capable of limiting accumulation of the salt ions in the shoot by favouring the retention of toxic ions in the roots (Munns & Tester, 2008).

In this study, it was found that number of fruits decreased with increase in severity of water stress. Abdulrahman and Nadir (2018) also found reduction in okra yield with increase in severity of drought stress. In the same vein Specht et al., (2001) found decrease in yield of soybean when it was raised under drought stress condition. Furthermore, Nahar and Ullah (2011) discovered yield reduction in two tomato cultivars when they subjected them to water stress condition. This reduction in yield under water deficit stress may be attributed to low cell expansion, less photosynthetic rate and leaf senescence (Wahid et al. 1997). Furthermore, the growth of drought-stressed plants is mostly limited by the osmotic effect of water deficit stress which results in reduced growth rate and low stomatal conductance. As water deficit stress increases, yields move towards zero because most plants (mesophytes) will not grow in high water deficit condition and are severely inhibited or even killed at very high stress level because they were not genetically bred to tolerate that stress level. Furthermore, reduction in yield could be attributed to reduction in number of leaves, plant height and number of branches found in this work. Yield reduction might equally be linked to action of water deficit to induce Fe^{2+}, K^{+}, and Ca^{2+} deficiencies (Singh et al., 2004) which resulted in yield losses (Hunshal et al., 1991).

The result of this study showed reduction in fruit mass as the severity of water deficit increased. Similarly, Ewetola and Fasanmi (2015) found the same trend when they subjected okra plants to water stress. In the same vein, Hussein (2011) discovered progressive reduction in okra yield as the severity of water stress increased. This reduction in yield could be attributed to reduction in

the parameters discussed above. This could be linked to action of water deficit to induce Fe^{2+}, K^{+}, and Ca^{2+} deficiencies (Singh et al., 2004) which resulted in yield losses (Hunshal et al., 1991). Also, salinity stress can cause decreased seed germination, seed growth, and dry matter production (Nautiyal et al., 1989).

From this study, dry mass was observed to have decreased with increase in water deficit. In a similar study, Bahreininejad (2015) found that fresh and dry masses in artichoke plant decreased in both moderate and severe water deficits which he attributed to a reduction in plant height and leaf area under water stress conditions. Furthermore, reduction of forage yield and and growth parametrs of crops were found by Saberi et al., (2012) in sweet corn (*Zea Mays* L.convar. *saccharata*), Perrier et al., (2017) in sorghum and Saeidnia et al., (2018) in orchardgrass (Dactylis glomerata). In the same vein, Stewart et al., (2007) and Travios and Karamane (2008) found decrease in dry matter content of plants when they were subjected to water stress. This observation could have resulted from reduction in the number and size of leaves, senescence and total abscission which reduced photosynthate production and consequently the dry matter accumulation. It could equally be attributed to decrease in leaf expansion and assimilation per unit leaf (Sobrado & Turner 1986), inhibition of leaf development with consequent reduced light interception (Nam et al., 1998), reduction in stomatal conductance which led to reduced carbon assimilation with consequent low biomass production (Medrano et al., 2002). Furthermore, it might be that there was build-up of chlorine in the leaves of plants suffering from water deficit and that triggered the synthesis of some forms of carboxylic acids which are converted to ethylene (a hormone) which triggered abscission in plants (Dodd, 2005). Finally, it should be noted that senescence may occur prior to accumulation of toxic ions and, therefore, osmotic phase is characterized by accumulation of abscisic acid (ABA) and a decrease in indole-3-acetic acid (IAA) (Albacete et al., 2008 and Ghanem et al., 2008). Reduction in yield could have resulted from combined effects of reductions in number of leaves, number of branches and plant height which led to drastic reduction in the production and distribution of photosynthate which ultimately caused a reduction the final yield. Decrease in the duration of developmental growth phases caused by water deficit could partly responsible for yield reduction through reduction in light interception over the shortened life cycle (Barnabás et al., 2008). Decrease in dry matter production was also partly due to reduction in the area of exposure of the leaves which are photosynthate production engines as a result of rolling or total dryness and death. Since okra is a C3 plant, its carbon dioxide utilization and fast assimilate translocation are not effective compare to its counterpart C4 which could make effective utilization of the resources and products. This in turn has resulted in lower yield with accompanied harm done to the plants through shortage of water. The proportion of assimilate partitioning will be based on the availability of dry matter which has already been reduced. In this case, unavailable materials cannot be distributed. Therefore, low dry matter production results in lower yield also.

Ether extract (crude fat) is an indicator of energy production (twice that of carbohydrate), a means of absorption of fat soluble vitamins, a protector of delicate organs in the body as well as an insulator against cold. Crude fat content in this work decreased with increase in severirity of drought stress. Similar to this result, Onwugbuta-Enyi (2004) and Martins –Junior et al., (2008) reported that crude fat content of cowpea seedlings was reduced by water stress. Bibi et al., (2012) also showed that crude fat of sorghum (sudangrass hybrids) decreased with imposition of water stress. Furthermore, Osuagwu and Edeoga (2013) found that water stress caused a significant reduction in the crude fat content of leaves of African basil (*Ocimum gratissimum* L.) and Bush buck (*Gongronema latifolium* Benth.). This might be because increase in water deficit triggered production of lipase which was responsible for breaking down of fat. Therefore, increase in water deficit resulted in decrease in crude fat content. The implication of this reduction as a result of breakdown of crude fat is that it leads to

formation of osmotic materials which aids plants in tolerating water stress.

Crude fibre is the part of an organic material (food or feed) that contains cellulose and other carbohydrates which are insoluble in either weak acid or alkali solution. High content of crude fibre implies low digestibility of the food or feed material as well as low energy and total digestible nutrient (TDN). There was increase in crude fibre with water deficit in this work. Other researchers like Essafi et al., (2006) and Sumithra et al., (2007) have equally reported increased ash production with increase in water stress in plants. Increase in these proximate substances. These results might be due to plants' increased production of crude fibre in response to water stress condition. Hale and Orcutt (1987) have observed that plants synthesize special high molecular proteins during water stress to assist them in resisting the effects of water stress. The implication of this result is that the fruits produced would be less useful as either food or feed. Although fruit bulking is through increase in fibre and water contents which are both disadvantages because they result in low shelf life, low dry matter content and low digestibility. However, high fibre content in okra is useful in stabilizing blood sugar by slowing down or regulating the rate at which sugar is absorbed from the intestinal tract and, therefore, useful for managing diabetes (Ngoc et al., 2008).

There was decrease in crude protein with increasing water deficit in this work. Similar to this result was that of Khalil et al., (2015) who observed that increasing water stress lowered crude protein percent in cowpea (Vigna unguiculata) plants. However, some researchers have reported contrary to this result of ours. For example, Rostamza et al., (2011) observed increase in crude protein content of pearl millet with increase in water stress. Similarly, Bibi et al., (2012) found that increase in moisture stress resulted in percentage of crude protein in sorghum (sudan grass hybrids). Finally, Fariaszewska et al., (2016) discovered increase in crude protein contents of forage grasses when they were subjected to mild water stress. It is generally concluded that positive or negative effect of water stress on forage crops depends on plant species. The result of this work might be linked to decreased synthesis of protein as well as increased activities of protein hydrolysing enzymes which led to accumulation of amino acids at the expense of protein (Pessarakli & Tucker, 1988). Furthermore, protein reduction could be attributed to higher ratio of Na^+ to K^+ at high water deficit level which inactivates enzymes and inhibits synthesis of protein. Moreover, low crude protein content can be linked to low nitrogen level in the plant as found in this study (Fig. 7) because the amount of nitrogen in the plants was used in calculating the crude protein content (Equation 4) Finally, reduction in protein content might also be attributed to low nitrate reduction activity (NR) which could have accounted for decline in plant growth. The implication of our result is that crude protein of crops could be purposely increased or decreased using water stress by choosing the appropriate plant species.

Chlorophyll is very important because it indicates the status of leaf nitrogen and nitrogen content is an indicator of the plant source strength (Gauthami et al., 2013). Chlorophyll content is an indication of nitrogen status of the plant and it is significantly decreased by exposure to moisture stress especially chlorophyll-a and chlorophyll-b (Ranjbarfordoei et al., 2000). If the chlorophyll content is high, it implies high source strength. High source strength will in turn lead to high yield and consequent high harvest index (Yu et al., 2012) if the assimilates are judiciously partitioned to the developing fruits. It has been made known that chlorophyll content has positive and significant correlation with both rice yield and harvest index (Sengupta & Majumder, 2009). There was decline in chlorophyll content as water stress increased in this work. This was equally reported by Manivannan et al. (2007) who also found that decrease in chlorophyll content was caused by water deficit stress in different sunflower varieties. Similarly, Guerfel et al., (2009) observed decrease in chlorophyll contents of two olive cultivars when they were subjected to reduced irrigation Farooq et al., (2009) also reported that both chlorophyll a and b are reduced drought stress. It should be noted that decrease in chlorophyll content or

unchanged level of chlorophyll is dependent on the duration and severity of drought (Zhang & Kirkham, 1996). The result of this study might be ascribed to damage done to the chloroplast by reactive oxygen species which are normally produced as a result of moisture or other environmental stresses (Smirnoff, 1995). Furthermore, water deficit induced reduction in chlorophyll content could be linked to loss of chloroplast membranes, excessive swelling, distortion of the lamellae vesiculation, and the appearance of lipid droplets (Kaiser et al., 1981). In the same vein, decrease in chlorophyll content could be as a result of water- deficit- induced weakening of protein-pigment- lipid complex and increased chlorophyllase activities (Ambede et al., 2012). This reduction in chlorophyll content together with reduced potassium uptake which results in K/Na antagonism resulted in impaired photosynthesis which consequently led to low yield. It should be noted that photosynthesis is adversely affected during moisture stress through lowering of chlorophyll level, disturbance of chlorophyll components and destruction of photosynthetic apparatus (Iturbe Ormaetxe et al., 1998). From the on-going, it is evident that the assertion that chlorophyll content has strong relationship with yield in rice (Sengupta & Majumder, 2009) is equally true for okra. However, there are still other contributing factors that influence yield. Therefore, chlorophyll cannot singly determine the yield magnitude except if other yield contributors are also in line.

There was decrease in ash contents with increase in severity of water stress in this research. In similar studies, Haji Hassani Asl et al., (2011) reported decrease in ash content with increase in severity of water stress in three forage crops which were corn, sorghum and millet. Also, Bibi et al., (2012) found reduction in ash content of sorghum-sudangrass hybrids with increase in severity of water stress. Moreover, Shoaei and Rafiei (2014) discovered significant decrease in ash content of two hybrids of maize. In cowpea, Khalil et al., (2015) found significant reduction in ashcontent of cowpea plants when raised under water stress conduction. This result could be attributed to effect of reduced soil nutrient availability and uptake as a result of decrease in soil water or it could be the consequence of limited energy source (carbohydrates) supplied by leaves being affected by water stress (Khalil et al., 2015). Furthermore, ash content signifies the level of minerals in the plant. However, increase in water deficit stress leads to progressive inhibition of mineral uptake by the plants. This is because plant roots have less access to soil nutrients (Steudle, 2000). This then results in having low ash content which is an indicator of the amount of minerals absorbed by the plants. This is confirmed in this study by the result on mineral contents of stems and leaves (Fig. 6-11) Furthermore, insufficient moisture might have led to tenacious adsorption of the minerals to the clay and the plant roots could not absorb the minerals. Moreover, the already absorbed minerals needed a pool of water for their translocation to the fruits was not available as a result of deficit water supply. Therefore, the fruits could not get enough minerals as the water deficit level increased and that resulted in low ash content.

From this study, it was found that the levels of N, P and K decreased with increase in water deficit stress. Similarly, reduction in potassium ion has been found in soy bean when subjected to water stress and the treatment led to reduced water potential too (Kaspar et al., 1989). However, there are some contrary reports from some researchers. For instance, increase in potassium content in creeping bent grass (Saneoka et al., 2004) and Ammopiptanthus mongolicus (evergreen xerophyte shrub) (Xu et al., 2002). As for nitrogen and phosphorus, Bista et al., (2018) Shoot, root, and total plant %N were significantly decreased by drought in all three species of grass (maize , barley and blue stem). Similarly, drought decreased shoot, root, and total plant %P in all species with the exception of shoot %P in big bluestem. These results could be linked to alteration of absorption and uptake nutrients under environmental stresses (Turan et al., 2007) like drought. Furthermore, absorption of nutrients is hampered by water shortage because the nutrients are no longer in solution. Not only this, the nutrients could have got fixed to the clay minerals. Hence, nutrient

availability becomes a problem and growth is checked. Decreases in NPK may not be attributable to effects of drought on translocation of nutrients from roots to shoot because magnitude of decrease is similar for root and shoot (Bista et a l., 2018). It should be noted that the fact that drought does not prevent totality of growth despite the fact that it reduces plant N and P. This implies that drought reduced the acquisition of nutrients more than it did the acquisition of water, and, hence, plant growth. Consequently, decreases in nutrient acquisition cannot be explained simply by decreases in water uptake (Bista et al., 2018). It has been established that drought can decrease the rate of nutrient uptake by plants independent of water uptake (Rouphael et al., 2012).

For instance, drought might decrease water uptake in the upper soil layers, in which soil nutrient concentrations are often higher, before affecting water uptake from deeper soil layers (Bradford & Hsiao, 1982). Drought can also decrease soil nutrient concentrations by decreasing soil microbial activity (Sanaullah et al., 2012). Also, moisture stress has potential of decreasing nutrient-uptake kinetics per unit root through decrease activity of enzymes involved in nutrient assimilation and this situation leads to nutrient uptake (Robredo et al., 2011) or through reduction of nutrient-uptake proteins expression in roots (Rouphael et al., 2012). The implication of this result (reduction in NPK contents with water stress) is that plants will have low ash contents as found in this work (Fig. 5).

Table 1. Effect of drought stress on plant height and number of branches

Treatment	Plant Height (cm)	Number of Leaves
Control	49.25^{a}	6.00^{a}
1 Day Interval	38.75^{abc}	4.00^{bc}
2 days Interval	34.00^{bc}	4.00^{cd}
3 Days Interval	26.75^{c}	4.00^{bc}

Means with the same letter(s) in the same column are not significantly different at 5% probability level.

Table 2. Effect drought stress on number of leaves and number of fruits of okra

Treatment	Number of Leaves	Number of Fruits
Control	7.00^{ab}	7.00^{a}
1 Day Interval	6.00^{ab}	4.00^{ab}
2 days Interval	6.00^{ab}	4.00^{ab}
3 Days Interval	5.00^{b}	2.00^{cd}

Means with the same letter(s) in the same column are not significantly different at 5% probability level.

Table 3. Effect of drought stress on fruits fresh weight and dry straw weights

Treatment	Fruit Fresh Weight (g/plant)	Dry Straw Weight (g)
Control	11.70[a]	5.01[a]
1 Day Interval	6.05[b]	3.12[abc]
2 days Interval	5.26[bc]	3.72[ab]
3 Days Interval	4.89[bc]	1.50[cc]

Means with the same letter(s) in the same column are not significantly different at 5% probability level.

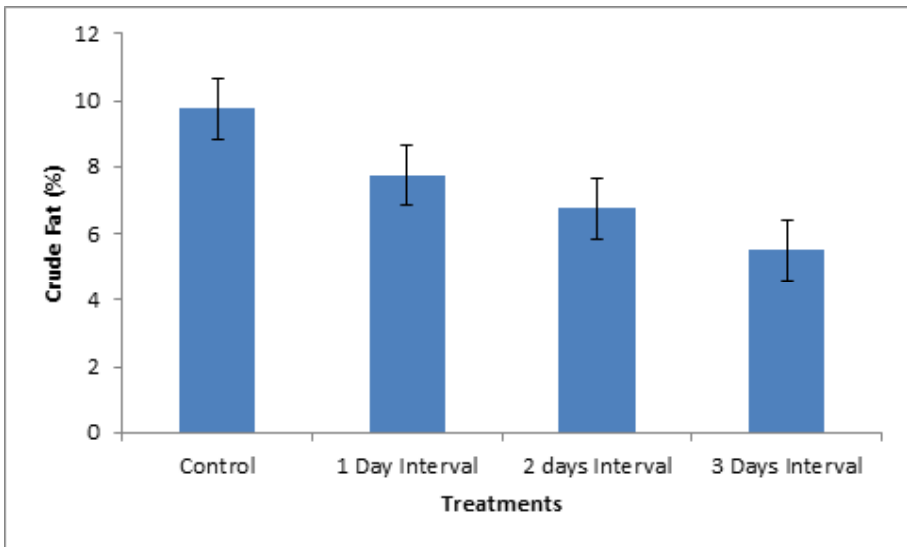

Fig. 1. Effect of drought stress on crude fat contents of okra leaves

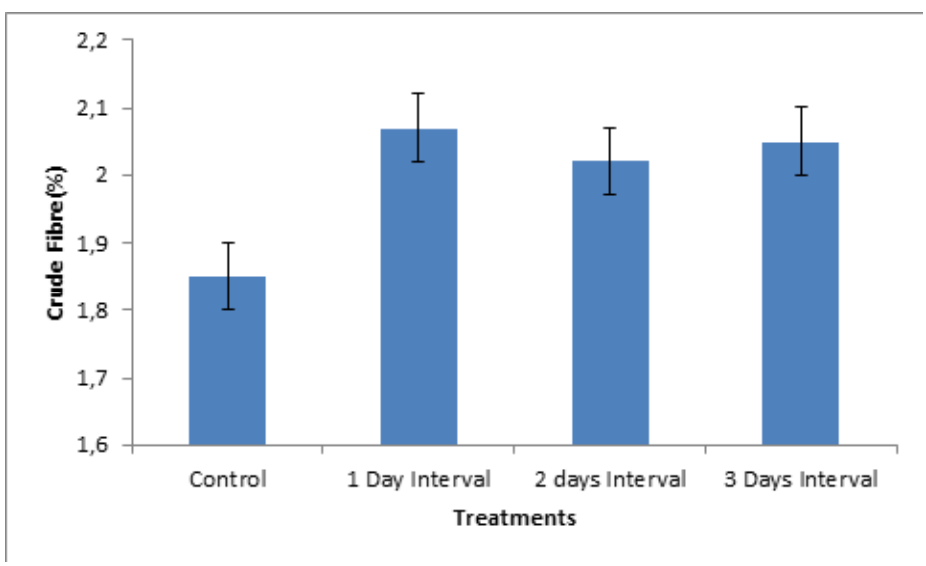

Fig. 2. Effect of drought stress on crude fibre contents of okra leaves

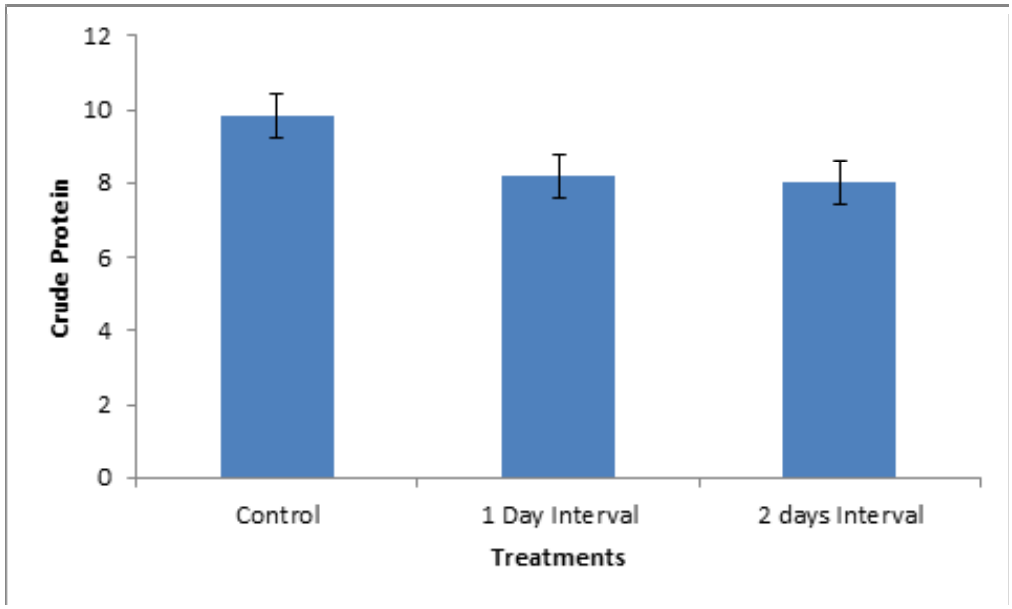

Fig. 3. Effect of drought stress on crude protein contents of okra leaves

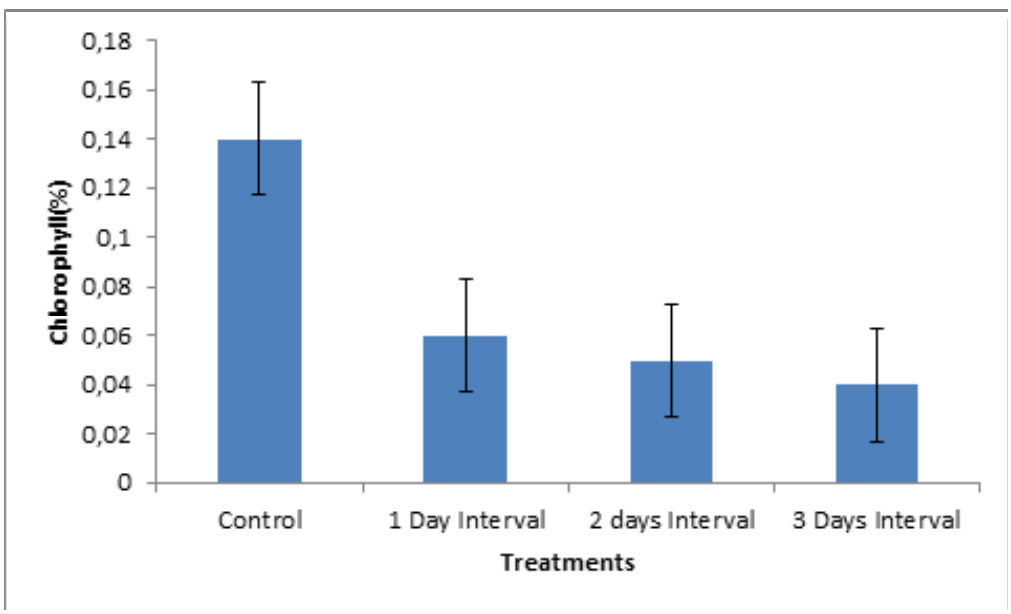

Fig. 4. Effect of drought stress on chlorophyll contents of okra leaves

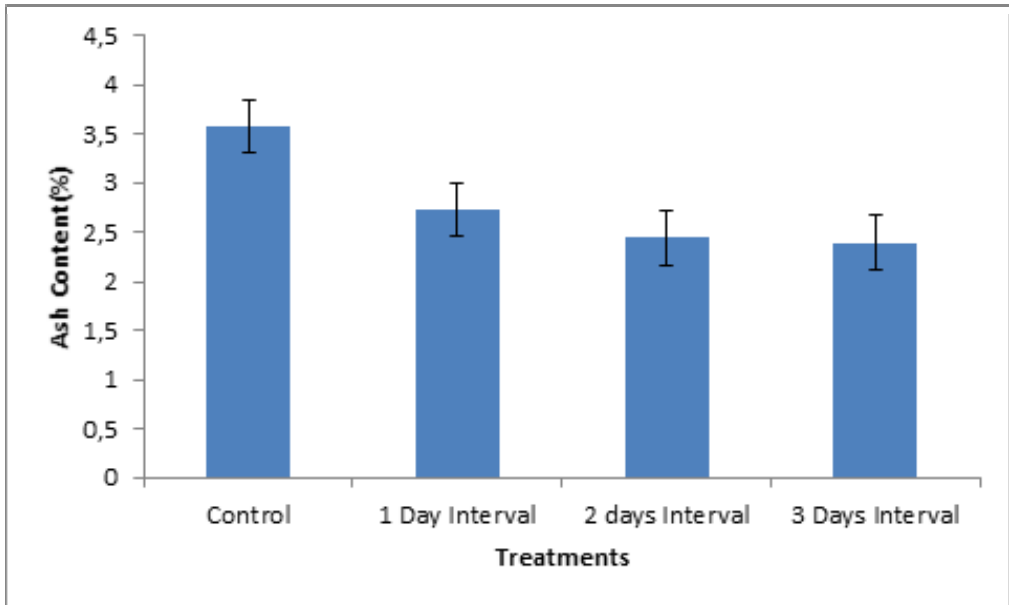

Fig. 5. Effect of drought stress on ash contents of okra leaves

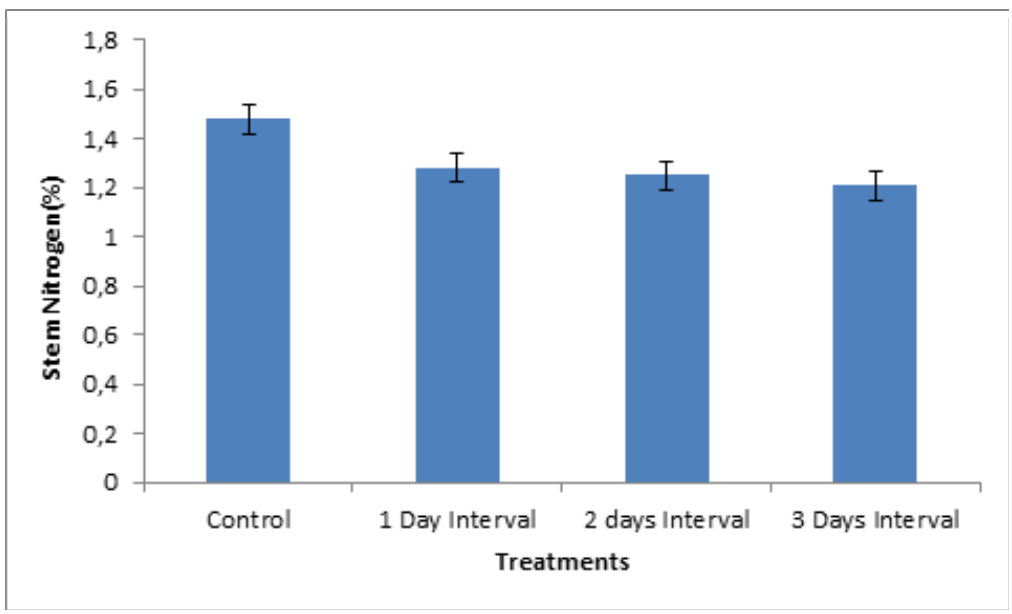

Fig. 6. Effect of drought stress on okra stem nitrogen content

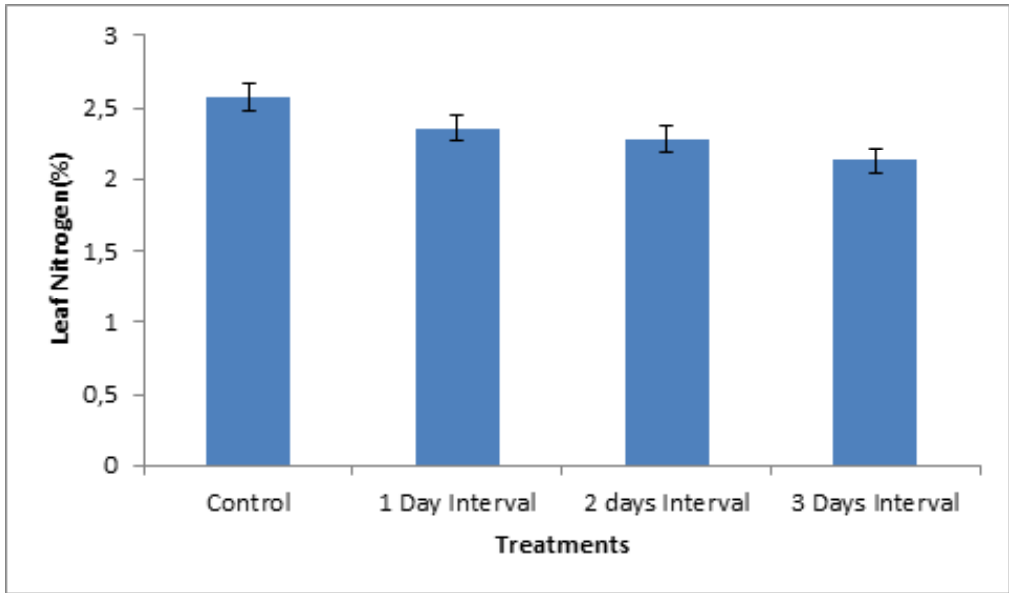

Fig. 7. Effect of drought stress on okra leaf nitrogen contents

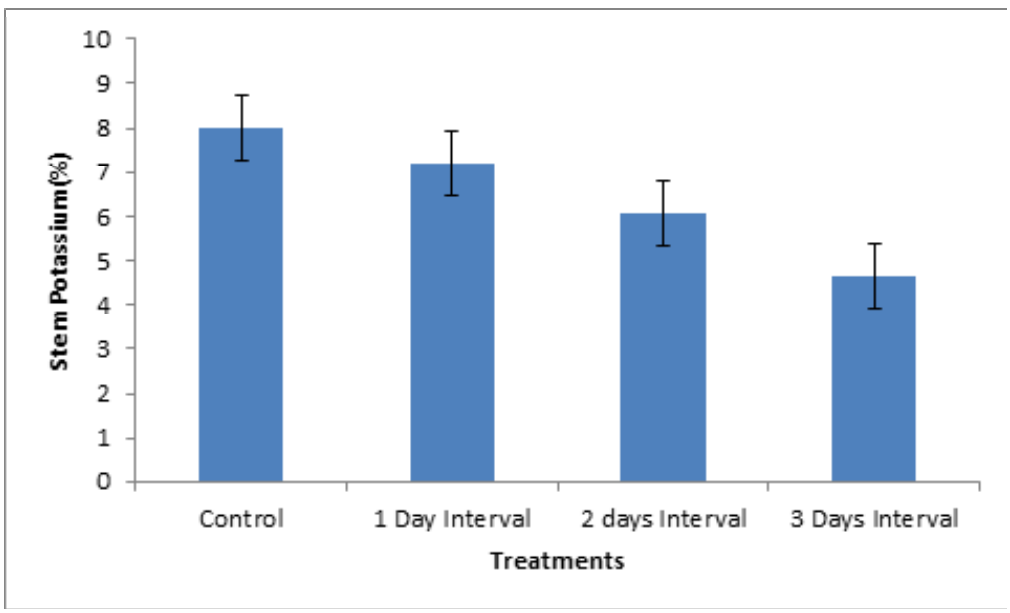

Fig. 8. Effect of drought stress on okra stem potassium content

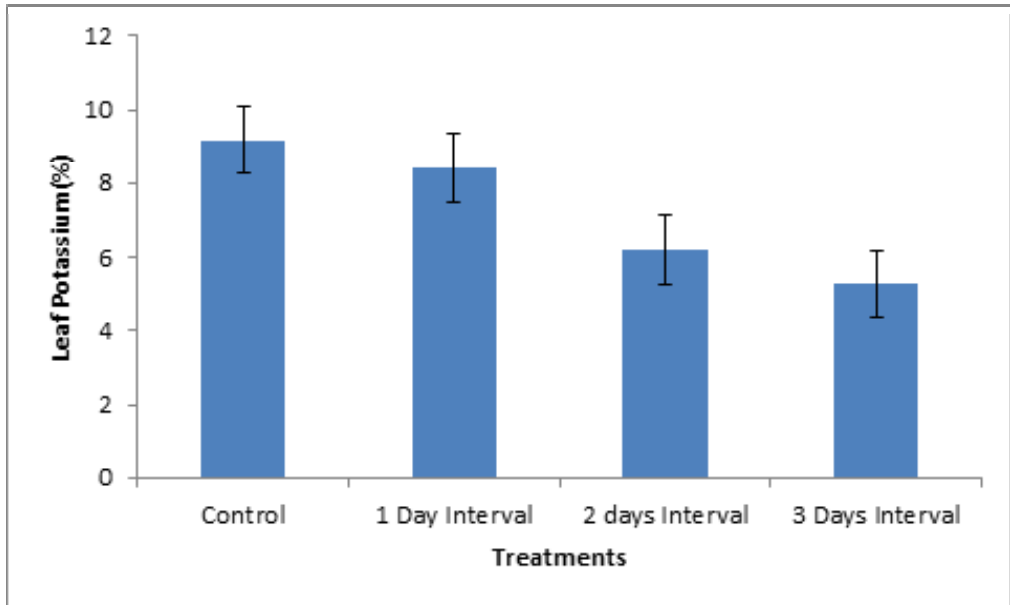

Fig. 9. Effect of drought stress on okra leaf potassium content

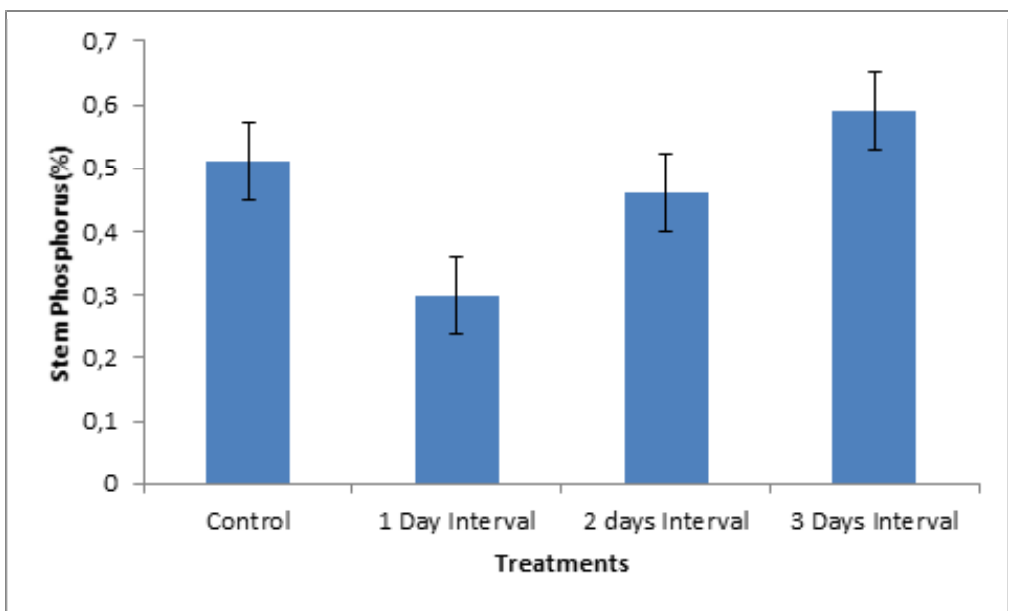

Fig. 10. Effect of drought stress on okra stem phosphorus content

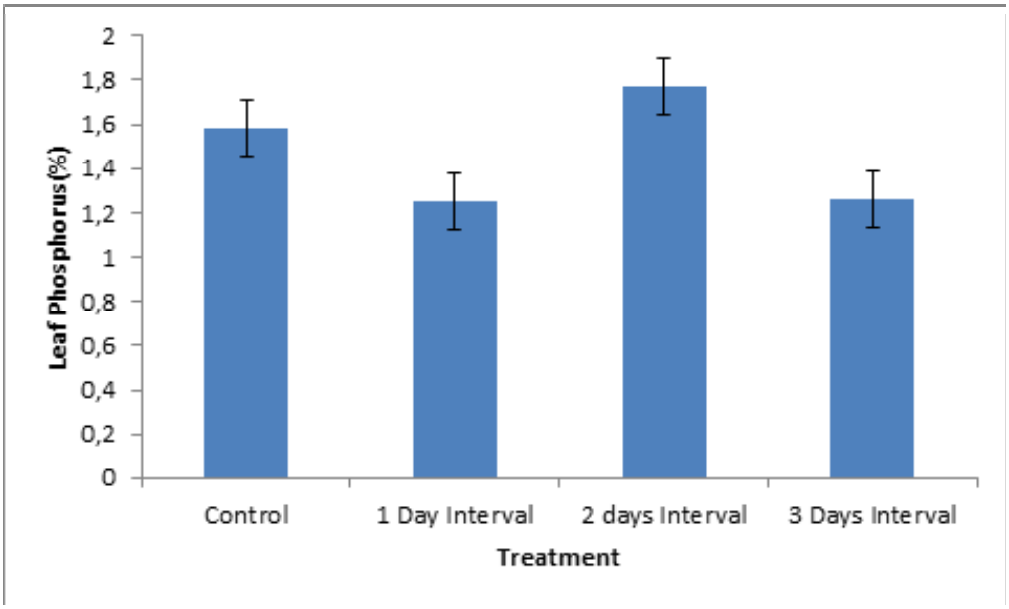

Fig. 11. Effect of drought stress on okra leaf phosphorus content

Conclusion

From this work, it was found that all proximate parameters decreased with increase in water deficit levels with the exception of crude fibre which increased with increase in water deficit. In the same vein, nitrogen and potassium levels decreased with increase in water deficit level in both leaves and stems. However, phosphorus levels in stems and leaves decreased with increase in water deficit level. It is, therefore, concluded that 17Lucky19 is susceptible to water deficit stress and water deficit tolerant or resistant varieties should be used whenever soil of areas with irregular rainfall is to be used for cultivating okra.

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