Screening of sweet potato ((*Ipomea batatas [L.] Lam.)* cultivars for drought tolerance

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Abstract**—** *The effect of drought on most agricultural crops results inmany problems for the producers in Nigeria and even other parts of the world. These problems include reduced vegetative parameters and yield loss which consequently lead to reduced income for the growers of the crops. The most direct way of avoiding drought is to discover or create drought tolerant varieties of sweet potato. Sweet potato is a crop which is part of the Nigerian diet due to its perceived nutritive values. A field experiment was carried out in Bowen University, Iwo to evaluate different cultivars of sweet potato for drought tolerance. The experimental design was laid in Randomized Complete Block Design with three replicates and three treatments including the mild water stress (32 days of drought), severe water stress (from the day of drought till harvest) and nowater stress (control). Results showed that under the control treatment, the highest yield was from the Local variety 1 with 127.63 g while the lowest yield under control was from Local variety 2 with 39.20 g. Under the mild water stress, the highest yield was from Introduced variety 1 with 272.46 g while the lowest yield was from Local variety 2 with 59.66 g. Under the severe water stress, the highest yield was from Local variety 1 with 41.15 g while the lowest yield was from Introduced variety 1 with 0 g. The highest yield among the three treatment methods was under the mild water stress treatment from Introduced variety 1 with 272.46 g.Therefore, variety 3, the local variety, is recommended under severe drought based on the above reason but under moderate drought,the Introduced variety i.e. variety 1 (orange fleshed sweet potato) is preferred because it had the highest yield and is also of high nutrient content compared to the other varieties.*

Keywords— drought, field experiment, sweet potato, tolerance.

I. INTRODUCTION

Sweet potato (*Ipomea batatas* [L.] Lam.) is an economically important crop in the world and particularly in Nigeria. Sweet potato occupies the position of seventh most important crop in terms of global production and in developing countries it ranks third in value of production and fifth in caloric contribution to the human diet [1]. Uganda, Nigeria, Tanzania, Angola, Burundi, Mozambique, Madagascar, Rwanda and Ethiopia, China, Indonesia, Viet Nam, India, USA and Japan are the top 15 sweet potato producers in the world [2]. It contributes significantly to the agricultural production of Sub Saharan Africa countries with roughly 3.2 million hectares and a production estimated at 13.4 million tons of tubers in 2005 [3]. A lot of root tubers are harvested per unit area and per unit time during relatively short periods of rain, meaning that it can withstand occasional drought, and is much more productive in less fertile soil than crops such as maize [4]. Sweet potato is considered as one of the major sources of food, animal feed and industrial raw materials. It has a significant contribution as an energy supplement and a phytochemical source of nutrition. It provides strong nutrients and ultimately good health to those who eat it. It possesses anti-carcinogenic and cardiovascular disease preventing properties [5].

Sweet potato is one of the main foods cultivated and consumed by most Nigerians.It is not too difficult to grow and is of great potential industrially and economically and due to its significance and importance, sweet potato is increasing in Nigeria's agriculture and food systems [6]. According to the survey conducted in six States in Nigeria by [7], the different forms of sweet potato utilization are boiling and eating with stew/palm oil, slicing and frying, roasting, boiling and eating as snack; boiling and pounding alone or with boiled yam/garri for eating with soup; cooking alone or with another crop to make pottage; slicing and sun-drying for milling into flour; feeding of vines and leaves to livestock; small tuberous roots as livestock feed; made into fufu like cassava; fresh leaves and young shoots consumed as vegetable. Also, in some African countries like Kenya, the storage roots are boiled and eaten, or chipped, dried and milled into flour which is then used to prepare snacks and baby weaning foods [8].

Sweet potato is considered as one of the major sources of food, animal feed and industrial raw materials. It has a significant contribution as energy supplement and phytochemical source of nutrition. It provides strong nutrients and thereby good health to those who eats it and possesses anti-carcinogenic and cardiovascular disease preventing properties [9]. Sweet potato varieties are outstanding source of vitamin C, B2, B6 and E, as well as dietary fiber, potassium, copper, manganese and iron, and are low in fat and cholesterol. The root parts of sweet potato contain 25-30% carbohydrates and 2.5-7.5% protein. In addition to this, it also supplies 200-300 mg 100 g^{-1} of potassium, 0.8 mg 100 g^{-1} of iron (Fe), 11 mg 100 g^{-1} of calcium (Ca) and 20-30 mg 100g^{-1} of vitamin C of its dry matter [10]. Industrially, Sweet potato yield starch, natural colorants, and fermented products such asbutanol, acetone, ethanol, wine, and lactic acid [11,12]. Leaves, stems, roots of sweet potato serve as livestock feed [13]. Leaf protein content of sweet potato contains twice that from the storage roots[14].

In spite ofthe high nutritious and economic potential of sweet potato, it faces with a lot of challenges and abiotic and biotic constraints such as drought, low soil nutrients, weeds, pests, diseases, lack of post-harvest storage facilities and improved varieties [15,16]. With climate change whose signs are already visible, agricultural production is facing alarming threats which can lead to serious problems of food insecurity [17] and unprecedented extreme hunger. Moreover, [18] reported that, Africa and especially West Africa will be seriously affected by the deleterious effects of climate change. The variability of climate change and the prevalence of extreme events, including drought, are a harsh reality for small farmers in Africa and in Nigeria who depend exclusively on rain-fed agriculture. Over the last decade, environmental stresses have become more frequent and are exacerbated by a rapid change in climate. It constitutes perhaps the most momentous environmental challenge of our time and poses serious threats to sustainable development worldwide and chiefly in most developing countries [19]. It has been estimated that drought is the most important environmental stresses and represents 70% of yield losses of cereal crops worldwide [20]. In addition, drought is regarded as environmental factors that leads to about 75% yield loss each year in the world [19]. The 2011 Texas drought has caused a record $5.2 billion in farming losses, for example, making it the most costly drought on record [21]. Among different abiotic stresses, drought is by far the most complex and devastating worldwide [22].

It has been demonstrated that sweet potato crop is sensitive to water shortage in the course of establishment, vine development and storage initiation[23]. [24] also reported that the water scarcity during critical periods of growth leads to irreparable consequences on yield. According to [25] drought is the chief production limitation of sweet potato in the areas where agriculture mainly dependents on rainfall. [26] revealed that water stress in sweet potato reduces vegetative and yield parameters in terms of quantity and quality. A variety is considered as drought resistant when it can produce high yield under water stress [27].[28]showed that the yield of most crops has been used as indicator for drought tolerance. Henceforth, sweet potato varieties tolerant to water stress should be able to produce more quantity and quality yields under drought conditions. This could be discovered only through screening of sweet potato genotypes under managed water stress conditions [29]. Thus, identification of cultivar performance under drought conditions is thus considered to be of vital importance. Therefore, the aim of this study is to improve stability and increase production of sweet potato in Nigeria through the development of drought tolerant cultivars. More specifically, the objectives are to (1) Evaluate sweet potato cultivars for drought tolerance under field conditions and (2) identify sweet potato cultivars withhigh yield and high quality.

II. MATERIALS AND METHODS

Description of the experimental site

The field experiment was carried out on sweet potato at Bowen University Teaching and Research Farm Iwo, Osun State, Nigeria. Iwo is a City in Osun State, Nigeria. The City formerly part of old Oyo State was later separated and became one of the major townships in Osun State, Nigeria. It has a latitude of 7° 38' 6.97" N and a longitude of 4° 10' 53.62" E. Rainfall and temperatures data were recorded daily from the date of planting till harvest.

Plant material

The material used in this study consisted of four (4) sweet potato cultivars. Two sweet potato cultivars (local variety 1 and 2) were obtained from Iwo farmers and the two other cultivars were newly introduced (introduced variety1 and 2). The introduced variety 1 is orange-fleshed cultivar which has been recognized as good sources of β-carotene, a precursor of vitamin A.

Experimental design and water stress

The soil was prepared, ploughed, harrowed and ridged. A Randomized Complete Block Design was used for the drought experiment. The experimental block unit was 10m by 2m with twelve beds. Each bed in a block measured 2m and the space between rows was 90cm and the space within a row was 30cm. There were three experimental blocks in total with 36 beds for the experiment and four cultivars of sweet potato. Sweet potato vines were cut to 30cm long each and planted on the 30th of November,

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2016 at the rate of six (6) vines per experimental unit with a depth of 15cm at a spacing of 30cm. The soil was thoroughly watered before planting.

For the firm establishment, sweet potato plants were watered daily in the evenings for about a month and 11 days i.e. from 1st of December 2016 to 11th of January 2017.

From January 12th 2017, there was imposition of water stress i.e. no watering of treatment 1 and treatment 2 while the treatment zero which served as control was watered daily in the evening until harvest. T1 was the mild drought stress and T2 was the severe moisture stress (no water was applied till harvest though there was some rainfalls toward the end of the experiment). In the mild moisture stress, drought was imposed for about a month and 6 days that is from January 12th to February 17th 2017. On the evening of February 17th, the watering of only T1 (mild drought stress) resumed again, therefore T0 (Control) and T1 (mild-drought stress) were the only treatments being watered till the date of harvest which was the 10th of April, 2017.

Measurement of vegetative and reproductive parameters

Data were collected on the following parameters;

- Vine length- The length of two most vigorous vines were taken using a measuring tape. The length was measured from the point of soil contact to the apical tip. The vines were straightened so as to get accurate reading.
- Petiole length- the stalk of the leaf was measured from the base of the leaf to the point of attachment to the stem.
- Leaf length- The length was measured from the tip of the leaf to the base or bottom of the leaf
- Leaf breadth- This was the measurement of the width of the leaf. The widest part of the bottom was measured from side to side.
- Internode length- This was obtained by measuring the distance between the nodes of the vines.
- Plant height- This was measured with a carpenters measuring tape, done by putting the tape on the ground and elongating the tape to check the height without straightening of the vine.
- Fresh weight of the vines per plant: it is the weight of above ground biomass before drying in the oven using a scale
- Dry weight of the vines after drying in the oven set at 85^0C for 4 days was also taken using a scale
- Fresh weight of the roots harvested: it is the weight of all storage roots at harvest per plant
- Dry weight of the root: it is weight recorded with a weighing balance after drying in the oven
- Total fresh weight (total yield): It is the total weight of storage roots
- Leaf tissue is most commonly used for RWC3 determination, measured as follows. A sample of leaf tissue was taken and the fresh weight was immediately determined, followed by flotation on distill water for up to 4 hours according to methods of Smart and Bingham (1974). The turgid weight was then recorded after the 4 hours, and the leaf tissue was subsequently oven-dried to a constant weight at about 75^0 C for 48 hours. RWC was calculated by following formula:

$$\text{RWC (\%)} = \frac{\text{Fresh weight} - \text{dry weight}}{\text{Turgid weight} - \text{dry weight}} \times 100$$

Statistical analysis

All data recorded were subjected to statistical analysis using “R” software to identify significant difference among the sweet potato cultivars used under the three treatments. ANOVA was performed for the assessment of the variation at 0.05 level of probability using Newman-Keuls Multiple Comparison-PostHOC test. In addition, Pearson correlation coefficient between traits measured was computed.

III. RESULTS

The temperature of Iwo in Osun state was recorded daily from the 12th of January till 10th of April as shown in Figure 1.From January to March, the period was very hot without recording any single rainfall.

Plant height

The mean plant height readings under the non-stress treatment are presented in Figure 2. The means for control ranges from 21.3 to 29.9 cm. The lowest 21.3 cm was recorded in variety 1 (introduced variety 1) and the highest 29.9 cm was from variety 2. Under the mild water stress, the readings vary between 20.67 and 29.4 cm. The lowest 20.67 cm was obtained from variety 4 (Local variety 2) and the highest 29.4 cm was from variety 2 (introduced variety 2). Under the severe water stress, the values range between 16.1 and 25.1. The lowest was 16.1 which was of variety 3 (Local variety 1) and the highest was 25.1 which was variety 2 (introduced variety 2). Overall, the mean plant height values range between 16.1 and 29.9 cm. The lowest value was under the severe water stress while the highest value was under the control treatment. There was no significant difference between the values obtained from the control and the mild water stress, but in the severe water stress there was a significant difference as there was a reduction in the mean values. Except in the case of variety 2 (introduced variety 2) which had a value of 25.1 cm.

Leaf width and length

Table 1 below shows the mean leaf width and length under non stress, mild water stress and severe water stress conditions. The mean leaf width values under the control ranges from 6.95 to 9.5 cm. The lowest value 6.95 cm was recorded in variety 4 (Local variety 2) and the highest was 9.5 cm from variety 3 (Local variety 1). Under the mild water stress conditions, the values range between 6.67 and 8.75 cm; the lowest was 6.67 from variety 4 (Local variety 2) and the highest was 8.75 cm which is variety 3 (Local variety 1). Under the severe water stress, the values vary from 6.35 to 8.37 cm. The lowest was 6.35 observed in variety 4 (Local variety 2) and the highest was 8.37 cm variety 3 (Local variety 1). In general, there was a slight decrease in leaf width under drought stress.

There was no significant difference amongst treatments but significant differences was observed between varieties as shown by ANOVA. The mean leaf length values under the control ranges from 8.1 to 11.6 cm, the lowest value was 8.1cm for Local variety 2 and the highest value was 11.6 cm obtained from Local variety 1. Under the mild water stress, the values range from 8.33 to 11.15 cm, the lowest value 8.33 was of Local 2 and the highest value 11.15 was from Local 1. Under the severe water stress, the values vary between 8.13 and 10.92 cm, the lowest value 8.13 was from Local2 and the highest value 10.92 cm was of Local 1. Overall, between the three treatments the mean leaf length values ranges between 8.1-11.6 cm the lowest value 8.1 is under the control treatment and the highest value 11.23 was also under the control treatment.

Internode and vine length performance

The Table 2 below shows the Mean Internode and vine length performance under non stress, mild water stress and severe water stress conditions. The mean internode values under the control treatment ranges between 4.13 and 7.17 cm, the lowest value 4.13 was from Local variety1 and the highest value 7.17 cm was from Introduced variety 1. Under mild water stress, the mean values varies from 3.88 to 6.70 cm, the lowest value 3.88 was recorded in Local variety 1and the highest value 6.70 was obtained from Introduced variety 1. Under severe water stress the mean values range between 3.35 and 4.60 cm, the lowest value 3.35 was from Introduced variety 2 and the highest value 4.60 was from Local variety 2. In general, the mean value between the three treatments ranges from 3.35 to 7.17 cm, the lowest value 3.35 was recorded under severe moisture stress while the highest value 7.17 was under the control treatment. There was significant difference in the values between varieties.

The mean vine length under non stress, mild water stress and severe water stress conditions are presented in Table 5. There was significant differences ($P < 0.05$) both among the four varieties and the three treatments. Local variety 2 and introduced variety 2 did better under drought compared to the other two varieties.

Petiole length

The Figure 3 below shows the Mean petiole length under non stress, mild water stress and severe water stress conditions The Figure reveals that as the moisture stress increases, there is a decrease in petiole length. The mean value between the three treatments ranges from 6.97 to13.2 cm, the lowest value 6.97 cm was under the severe water stress and the highest value 13.2 was under the control.

Plant fresh weight

There were significant differences ($P < 0.01$) between varieties and treatments (Table 3) and as shown in ANOVA table in appendix 4. It was observed that as the period of drought increases, there was decrease in plant fresh weight. Under the moderate water stress the mean values ranges between 300 and 733.33 g, the lowest value 300 was obtained from the Introduced variety 1 and the highest value 733.33g was recorded in Introduced variety 2. Under the severe water stress, the mean values vary from 233.33 to 633.33 g, the lowest value 233.33 was for Introduced variety 1 and the highest value 633.33 was for Introduced variety 2.

The table below shows the Mean plant dry weight under no water stress, mild water stress and severe water stress conditions. The average value of dry weight decrease in all the drought treatments except in the introduced variety 2 between the control and the moderate moisture control. Under the severe water stress, the mean values ranges from 50 to 133.33.g, the lowest value 50 was recorded in the Introduced variety 1 and the highest value 133.33 was obtained from the Local 2.

Effect of drought of sweet potato yield (total root fresh weight) and dry weight

The results of fresh weight is shown in Table 4. No fresh weight was recorded for the introduced variety 1 under severe drought. These results of this table also reveal that there is increase in the yield of moderate moisture stress compared to the control for the introduced variety 1 and introduced variety 2 and the local variety 2. Though the fresh weights of these three varieties significantly reduced at severe drought stress. Under severe moisture stress, local variety 1 performed better (189.00 g) than others followed by local variety 2 and the introduced variety 2.

There was significant difference between the total dry weights under no drought stress, the lowest value 32.63 was of the introduced variety 1 and the highest value 215.13 was obtained from Local 1. Under mild water stress, the values range between 70.83 and 128.50, the lowest value 70.83g was recorded from introduced variety 1 and the highest value 128.50 was from Local 1. There was no significant difference between introduced variety 1 and Local 2 and there was also no significant difference between introduced variety 2 and Local 1. Under severe water stress, the values range between 0g and 54.47g.

Effect of drought on sweet potato yield per plant (fresh weight) and dry weight

The introduced variety 1 performed much better than other in term of fresh root weight per plant and was highly significant than the others. Though no fresh weight was obtained under severe stress. As observed with the total fresh weight under severe stress, local variety 1 performed better than others followed by local variety 2 and the introduced variety 2. The table below shows the effect of drought of sweet potato yield per plant (fresh weight) under control, mild water stress and severe water stress conditions.

Effect of drought on Relative water content

The analysis of table 6 reveals that in the four cultivars used, it was observed as the drought period increases the relative water content decreases. But this decline in relative water content was not pronounced in variety 3 and variety 4. Though the ANOVA that there was no significant different amongst different treatment.

Relationship between eleven traits related to drought tolerance in sweet potato

Table 7 shows the correlation coefficient of the morphological and yield parameters measured. Total fresh root weight (total yield) and total dry root weight were significantly and positively correlated to the following traits: leaf length ($r = 0.34$, $P < 0.05$), and plant height ($r = 0.35$, $P < 0.05$) but negatively correlated with vine length ($r= 0.15$, $P> 0.05$). Fresh root weight per plant and dry root weight were positively and significantly correlated with Total fresh root weight ($r= 0.70$, $P<0.01$) total dry root weight ($r = 0.60$, $P < 0.01$), and internode length ($r= 0.40$, $P< 0.05$) while there were positive and not significant correlation with vine length, petiole length, leaf length, leaf width and plant height.Leaf length was positively and significantly correlated with leaf width ($r= 0.60$, $P< 0.01$)

IV. DISCUSSION

As the effect of climate change get exacerbated and water resources become more restrictive for agricultural uses, the creation of drought-tolerant cultivars isof paramount importance[30]. Henceforth, part of the objectives of this study was to identify sweet potato cultivars that could be less affected by drought stressthat is with water use efficiency and without a significant loss of fresh roots i.e. yield and without losing the merchant quality and nutrition.

As shown in Figure 1 the temperature ranges between 30^{0}C and 38^{0}C and occasionally 40^{0}C between the month of January and April. The relative humidity (data not shown) was not high an indication of drier air which could have led to high evapo-transpiration and as a result this could affect the availability of water in soil for crop production. Therefore, the period of this study was characterized by scorch sunlight, drier air and significant evapo-transpiration.

There was no significant difference between the values obtained from the control and the mild water stress though slight differences were noted, but in the severe water stress there was significant differences as there was a reduction in the mean values of aboveground and underground parameters. This results are similar to [31] who reported that significant differences in aboveground biomass amongst genotypes were observed, which indicates that genotypes differed significantly in their tolerance to drought conditions. For instance, the effect of drought on plant height of the four varieties used decreased across different moisture conditions. But introduced variety 2 and local variety 2 did better compared to the other 2 varieties.

No significant difference across the three treatments i.e. the control, mild water stress and the severe water stress was observed. This could be explained by the fact that water stress did not significantly affect leaf width. Therefore it can be hypothesized that the higher leaf width of variety 1 and variety 3 could help in sunlight interception for better photosynthesis and thus to high dry matter production. Meanwhile, there was a significant difference in leaf width between the four varieties, indicating that sweet potato varieties respond different to water stress.

There were no significant differences between the leaf length, internode length and petiole length values recorded in control, moderate or mild water stress and severe moisture stress, though a slight differences were observed at severe drought level. This illustrates that drought did affect the three vegetative parameters but there were not significantly affected. [32] reported that biomass and morphological parameters such a main stem length, internode diameter and length, leaf area and number decreased in response to drought stress. Moreover, the study of [33] carried out in South Africa revealed that the internode diameter was reduced by 12% to 50% across the sweet potato accessions used.

The vine length revealed a decrease in vine length especially under the severity of water stress. Under moderate water stress the lowest vine length value was 52.83 from Introduced variety 2 the highest value was 125.92 cm for the Introduced variety 1. Under the severe water stress, the lowest value was 38.3 of the Introduced variety 2 and the highest value was 109.13 of Local 2. This demonstrates that Local variety 2 performed better under severe moisture stress when compared to other varieties. Our results are consistent with those of [32] and [33] observed that the reduction in stem length (relative to the control) of 15 accessions exposed to drought stress varied considerably from 16.1% to 46.0%.

Highly significant and positive correlations were observed between the 11 characters studied under drought conditions. Table 7 shows total yield and yield per plant, the ultimate indicator for abiotic tolerance, was positively and significantly correlated with leaf length ($r = 0.34$, $P < 0.05$), and plant height ($r = 0.35$, $P < 0.05$) and positively correlated with plant weight, leaf width, petiole length, and internode length. This illustrates the importance of these parameters in breeding program for drought tolerance.

The results obtained from the plant fresh weight indicated that the introduced variety 2 was higher than other varieties which indicates that the varieties responded differently and some are more sensitive than other under drought stress. The results from plant dry weight illustrate that Local variety 2 and introduced variety 2 accumulated more dry matter than the other varieties. The reduction in plant fresh weight and plant dry weight obtained in this study is consistent with those of [33] and [32].

Under moderate drought stress all the four varieties performed well, indicating that they can only tolerate mild stress. Under severe drought, variety 1 did not produce any tubers. This indicates that this variety was more sensitive than other varieties under severe drought. Therefore, variety 1 can only cope under moderate moisture stress. This study is similar to [34] who reported that water stress sensitiveness of Orange-Fleshed Sweet Potato is considered as one of the major drawbacks of this crop type and currently available varieties do not allow sustainable and enduring production in drought prone regions. Variety 3 performed better in term of yield than other varieties under severe drought. [35] and [33] indicated that storage root drymass is correlated positively with vegetative growth. Similarly, [36] reported a reduction in root dry mass under stress conditions.

The accumulation of dry matter four all the four varieties was excellent under moderate drought stress. Under severe drought, the highest root dry matter was recorded in variety 3 followed by introduced variety 2 and variety 4 under severe moisture stress. [23] reported a reduction in root dry mass under water stress condition. The variation in dry matter content can also be dependent on various factors such as soil type, pest, diseases, cultivar and climate [36].

V. CONCLUSION

Overall, taking all these above data into consideration and looking at the ones which are least affected by drought to most of the factors variety 1 was least affected by drought on total dry weight under moderate drought stress, while variety 2 was least affected by drought on, plant height, petiole length and plant fresh weight. Variety 3 was least affected by drought on, leaf width, leaf length, tuber fresh weight (total yield), sweet potato yield per plant (fresh weight/plant) and dry weight. Variety 4 was least affected on internode, vine length, and plant dry weight. Variety 3, the local variety, is recommended under severe drought based on the above reason but under moderate drought Introduced variety i.e. variety 1 (orange fleshed sweet potato) is preferred based on the fact that it had the highest yield and also is of high nutrient content compared to other varieties.

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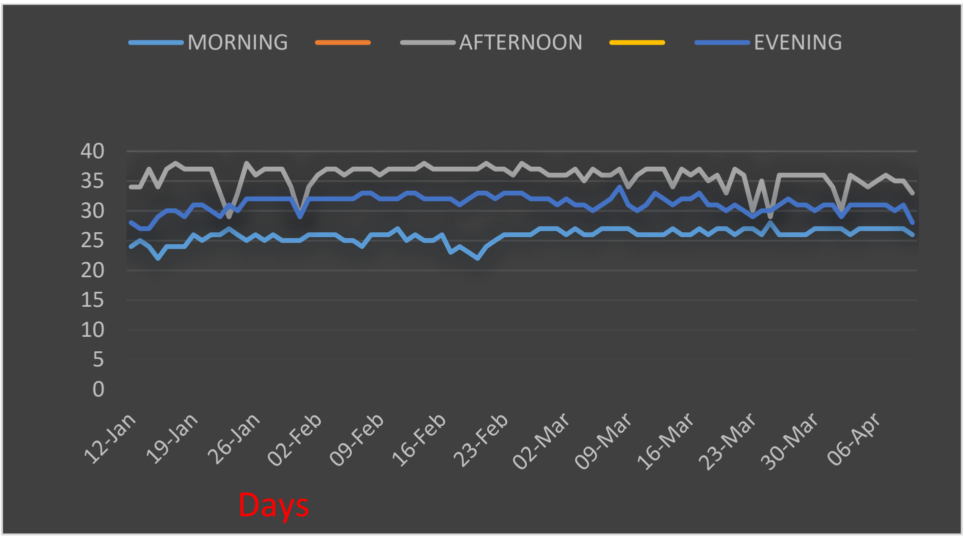

Fig.1: Daily temperature in Iwo in the course the experiment

Table.1: Mean leaf width and length under non-stress, mild water stress and severe water stress (Average ± Standard deviation)

	Leaf width			Leaf width		
Varieties	Control	Mild water stress	Severe water stress	Control	Mild water stress	Severe water stress
Variety 1	9.22 ±0.45	8.6 ±0.49	8.1 ±1.26	9.77 ±0.97	9.65 ±0.55	8.83 ±0.82
Variety 2	7.63 ±0.46	6.82 ±0.33	6.62 ±1.01	11.2 ±0.28	11.02 ±0.51	10.6 ±0.33
Variety 3	9.5 ±1.43	8.75 ±0.66	8.37 ±2.15	11.6 ±0.13	11.15±1.19	10.9 ±3.03
Variety 4	6.95 ±0.63	6.67 ±0.63	6.35 ±0.28	8.1 ±0.75	8.33±0.42	8.13 ± 0.17

Different letters in the same column show significant difference at 0.05 probability level for vine length.

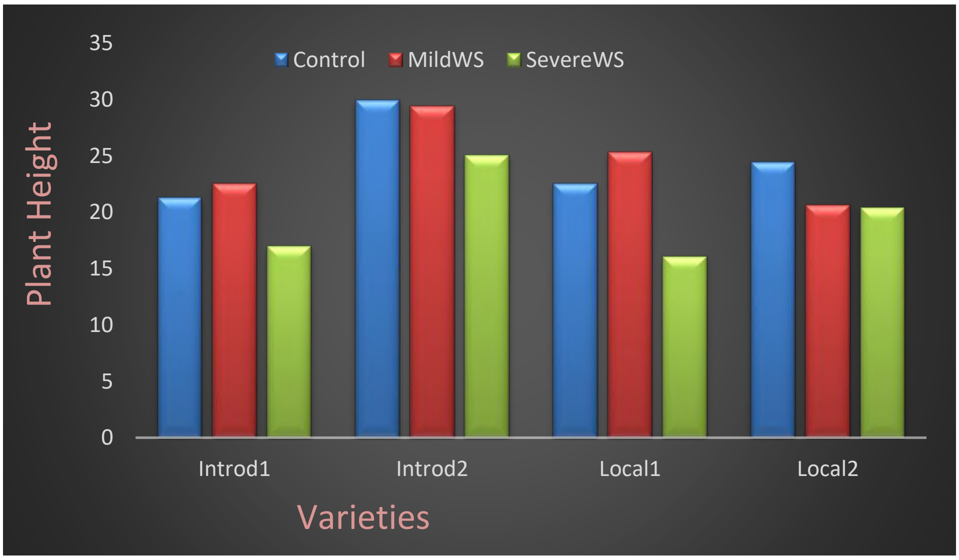

Fig.2: Mean plant height under non-stress, mild water stress and severe water stress

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Table.2: Mean performance of Internode and vine length under non-stress, mild water stress and severe water stress

	Internode			Vine length		
Varieties	Control	Mild water stress	Severe water stress	Control	Mild water stress	Severe water stress
Variety 1	7.17 ± 3.57	6.70 ±3.32	4.48 ±0.75	131.0±39.98 a	125.92± 51.11 a	50.53 ± 18.84 b
Variety 2	4.82 ±0.50	4.35 ±0.31	3.35 ±0.51	69.37±7.30 c	52.83± 18.84 c	38.3 ± 5.79 b
Variety 3	4.13 ± 0.10	3.88 ±1.40	3.97 ±0.43	101.53± 25.82 b	95.77± 29.92 b	55.7 ± 29.92 b
Variety 4	5.58 ± 0.98	5.10 ±0.13	4.60 ±0.65	131.48 ± 60.30 a	113.45± 43.31 a	109.13 ± 26.23 a

Different letters in the same column show significant difference at 0.05 probability level for vine length.

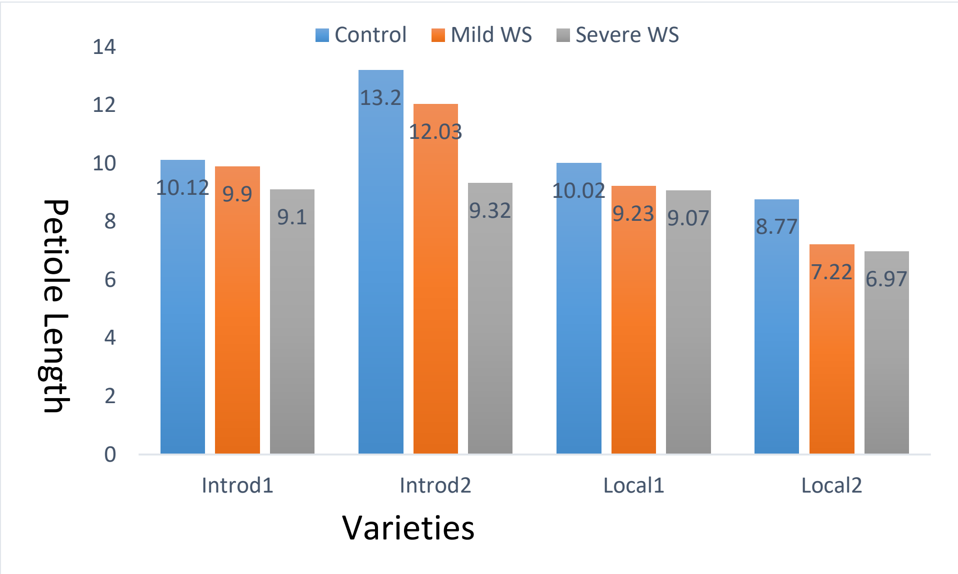

Fig.3: Mean petiole length under non-stress, mild water stress and severe water stress

Table.3: Mean plant fresh weight and dry weight under no water stress, mild water stress and severe water stress

	Plant fresh weight			Plant dry weight		
	Control	Mild water stress	Severe water stress	Control	Mild water stress	Severe water stress
Variety 1	333.33^{a}	300^{a}	233.33^{a}	100	83.33	50
Variety 2	866.67^{b}	733.33^{b}	633.33^{b}	116.66	116.66	100
Variety 3	600^{b}	500^{c}	366.66^{c}	183.33	116.66	66.66
Variety 4	666.66^{b}	566.66^{c}	533.33^{b}	216.67	166.66	133.33

Different letters in the same column show significant difference at 0.05 probability level for plant fresh weight.

Table.4: Effect of drought of sweet potato yield (fresh weight and dry weight)

	Total Root fresh weight (yield)			Total Root dry weight		
Varieties	Control	Mild water stress	Severe water stress	Control	Mild water stress	Severe water stress
Variety 1	132.83c	294.10a	0d	32.63c	70.83b	0b
Variety 2	324.87b	397.60a	87.00b	120.63a	115.27a	34.30a
Variety 3	607.667 a	339.77a	189.00a	215.13a	128.50a	54.47a
Variety 4	182.00c	238.63a	96.00b	63.63bc	83.33b	32.200a

Different letters in the same column show significant difference at 0.05 probability level

Table.5: Effect of drought of sweet potato yield per plant (fresh weight) and dry weight

Varieties	Root fresh weight per plant			Root dry weight/plant		
	Control	Mild water stress	Severe water stress	Control	Mild water stress	Severe water stress
Variety 1	66.417bc	272.456a	0d	16.32a	66.26a	0b
Variety 2	80.798b	99.40b	23.32b	29.94a	28.82a	9.42a
Variety 3	127.63a	67.953b	41.15a	45.45a	25.70a	11.88a
Variety 4	39.20c	59.66b	19.20b	13.67a	20.83a	6.44a

Different letters in the same column show significant difference at 0.05 probability level

Table.6: Mean performance of Relative water content under drought condition

Varieties	Control	Mild water stress	Severe water stress
Variety 1	86.31a	80.51a	73.31a
Variety 2	81.55a	78.11a	72.32a
Variety 3	78.72a	78.70a	76.21a
Variety 4	77.03a	75.24a	74.09a

Table.7: Correlation coefficient among the 11 characters

	vlg[a]	petlg	leafL	leafw	intL	plhg	plwg	TotFrW	TotDrW	FrWP	DrWP
vlg	1										
petlg	-0.16	1									
leafL	-0.15	0.49**	1								
leafw	0.24	0.13	0.6**	1							
intL	0.29	-0.01	-0.15	0.17	1						
plhg	-0.34*	0.13	0.27	-0.05	-0.4	1					
plwg	-0.28	0.39*	0.20	-0.33*	-0.15	0.44**	1				
TotFrW	-0.02	0.06	0.34*	0.17	0.03	0.35*	0.21	1			
TotDrW	-0.06	0.02	0.34*	0.16	-0.03	0.38*	0.26	0.99**	1		
FrWP	0.22	0.02	0.19	0.22	0.40*	0.04	-0.07	0.69**	0.59*	1	
DrWP	0.16	0.03	0.24	0.21	0.33	0.14	0.01	0.80**	0.73**	0.98**	1

*P<0.05, ** P<0.01

[a]Vlg= vine length, petlg= petiole length, leafL= leaf length, leafw= leaf width, intL=internode length, plhg= plant height, plwg= plant weight, TotFrW= total root fresh weight, TotDrW = total root dry weight, FrWP= average root fresh weight/plant, DrWP= average root dry weight/plant