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Greenhouse and Field Evaluation of Selected Sweetpotato (*Ipomoea batatas* (L.) LAM) Accessions for Drought Tolerance in South Africa

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Abstract

Sweetpotato is a major staple food in the world. It is a good source of carbohydrates, vitamin A, vitamin C and protein. The maximum production potential of the crop is being hampered by severe drought which ravages most parts of Africa. The main aim of this study therefore was to screen accessions of sweetpotato for drought tolerance in a quick screening method, followed by field screening with a view to identify accessions that can perform well under water stress conditions. Fifty sweetpotato accessions consisting of cultivars and breeding lines collected from the ARC-VOPI gene bank were planted for drought screening in the glass house for six weeks during which water was withheld to induce stress. Observations were made on number of dead plants and days to wilting point. The results were analyzed and 12 best performing accessions were selected for field trials. The field trial was carried out in Lwamondo, Limpopo province, a drought prone area in South Africa, under rain-fed conditions. The best performing accessions were Zapallo, Tacna, Ejumula, 2004-9-2 and Ndou.

Keywords

Accessions, Drought, Sweetpotato, Tolerance

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1. Introduction

Rainfed agriculture covers 80% of the world's cultivated land, and is responsible for about 60% of crop production [1]. Drought, amongst other environmental factors, contributes to about 75% yield loss each year in the world [2]. Agriculture is the largest consumer of water in the world and in the drier areas of the world including South Africa which is regarded a water-stressed country [3]. The use of water for agriculture can exceed 90 percent of consumption [4]. Global warming is also predicted to affect developing countries severely where agricultural systems are most vulnerable to climatic conditions. [5] predicted considerable increases in number of hot days due to climate change in Limpopo Province South Africa, a popular sweetpotato growing region which will be detrimental to productivity.

The Food and Agricultural Organization of the United Nations [2] estimates that by 2025 approximately 480 million people in Africa could be living in areas with very scarce water, and that as [1] climatic conditions deteriorate, 600,000 km^2 currently classed as moderately constrained will become severely limited. It is thus essential to improve water use efficiency in agriculture. This will require an integrated approach to water resources management to encourage an efficient and equitable use of the resource, and to ensure sustainability. The identification of crop varieties with increased tolerance to drought is therefore an important strategy to meet global food demands with less water. According to [2] the inadequate knowledge of varieties and environmental conditions is causing drought to have such a high impact on yield.

Sweetpotato (*Ipomoea batatas*) is a major staple food in Africa, Asia, the Caribbean, and South America, where they are important sources of carbohydrates, vitamins A and C, fiber, iron, potassium, and protein [6]. Sweetpotato is also used as animal feed. Increasing recognition of the great potential of the sweetpotato crop as a nutritious food for humans and animals has resulted in intensified research efforts to enhance production and consumption in recent decades [7]. It has the advantage over other crops in the fact of providing a quick yield during a short growth period and providing a stable productivity less affected by climatic factors [8]. Sweetpotato also has flexible planting and harvesting times, tolerates high temperatures and low fertility soils. It is drought tolerant and easy to propagate. Furthermore, compared to other crops, sweetpotato requires fewer inputs and labour making it particularly suitable for households threatened by migration or diseases such as HIV/AIDS [9]. The crop is grown over a broad range of environments and cultural practices and is commonly grown in low-input agriculture systems [10].

Sweetpotato, despite being a hardy crop by nature, is sensitive to water deficits particularly during the establishment period including vine development and storage root initiation [11]. Drought often is a major environmental constraint for sweetpotato production in areas where it is grown under rain fed conditions [12]. However, different genotypes may respond differently to limited quantities of soil water [12] [13]. Selection for good cultivar performance under drought conditions is thus considered to be of major importance. Drought necessitates additional irrigation periods, and this increases the overhead production costs. South Africa is regarded as being susceptible to water stress conditions due to prevalence of drought [14]. Research into drought tolerant plants is being intensified in order to minimize its overall impact on the agricultural enterprise. The development of drought tolerant sweetpotato varieties will increase profitability to farmers by potentially limiting irrigation and associated production overhead costs.

Genotypic variability exists for drought tolerance with some clones performing better under drought conditions [13]. Selection and improvement of adapted genotypes for a particular environment can therefore, be done with the appropriate equipment and using selection criteria associated with drought tolerance [13]. With this genetic management option, drought-tolerant varieties, once developed, would be a low economic input technology that may be readily acceptable by resource-poor, rain fed, small land holding farmers. Consequently, the objectives of this study is to screen breeding lines and land races for drought tolerance in a quick screening method, evaluate the selected breeding lines and land races for drought tolerance under field condition and identify accessions that can perform well under water stress conditions without a significant loss of yield and quality.

2. Materials and Methods

2.1. Pre-Screening

The pre-screening was carried out in the drought screening glass house at Agricultural Research Council-Vegetable and Ornamental Plant Institute (ARC-VOPI), South Africa (Latitude 25.604˚S, Longitude 28.345˚E and Altitude 1159 m). The plant materials used for this experiment were 50 sweetpotato accessions obtained from the gene bank of ARC-VOPI (**Table 1**). The materials consisted of local cultivars, imported accessions and ARC breeding lines/accessions. The pre-screening of accessions was done between March and August 2008. Stem cuttings of the 50 accessions were planted in plastic boxes of size 155 cm × 77 cm × 23 cm. The boxes were filled with a special soil mixture (5:2:2 sand:soil:vermiculite). Sweetpotato cuttings of about 30 cm long from each accession were cut and planted 2 eyes/nodes below the surface and 3 eyes/nodes above the surface for uniformity of development. Eight accessions were planted in each box with the plant spacing 15 cm between rows and 10 cm between plants and a box contained ten rows (5 plants/row). In each box 8 accessions and 2 control accessions were planted to serve as positive and negative controls namely Lethlabula (drought tolerant and positive control) and Resisto (drought sensitive and negative control). The design was randomized complete block design (RCBD) with 6 replicates consisting of a total of 38 boxes. The experiment was watered for 10 - 14 days for establishment after which water was withheld to induce stress. The experiment was concluded 60 DAP when 60% - 70% of the plants showed severe stress and wilting.

2.2. Field Experiment

The field trial was done at Lwamondo Agricultural Station in Thohoyandou in Limpopo Province, South Africa between March and September 2009. It lies at 23.06'S latitude and 30.38'E longitude with an altitude of 618 m above sea level. Climate conditions are subtropical with average annual rainfall of 752 mm with over 80% occurring between October and December. The average maximum and minimum temperature in the area is between 28.5˚C and 13.7˚C.

The 12 accessions used for the field trials were Zapallo, Resisto, Ejumula, Tacna, 1999-3-1, 2004-16-1, 2004-5-2, 2004-9-2, W-119, Phala, 2003-24-2 and Ndou. These consisted of 10 accessions selected based on the results of the pre-screening trial (**Table 2**), Resisto, the drought sensitive negative control and Ejumula which was an addition from the previous box experiment. Ejumula was found in previous experiment to be drought tolerant and was therefore used as a replacement for cultivar Japon Tresmesino Selecto which did not have enough planting material available for the field trial. An area of land measuring 20 m × 60 m was used for the trial. Field preparation included making ridges of 0.3 m high and spaced 1 m between the center of the ridges. Before planting Limestone Ammonium Nitrate (LAN, 28% N) was applied at 150 kg/ha (110 g/plot) and super grow (18.5% P) was applied at 150 kg/ha (110 g/plot) to the field by broadcasting method and incorporated into the soil. The cuttings were planted the next day in a triple row of 8 plants per row (24 plants/plot) with spacing of 1 m between rows and 0.3 m between plants and replicated 5 times. The design was randomized complete block design (RCBD). Two border rows were planted on each side of each block. The whole plot was watered using overhead irrigation for 7 days to facilitate plant establishment after which water was withheld till the end of the experiment. Weeding was done manually to remove unwanted plants.

2.3. Data Collection

2.3.1. Plastic Box Pre-Screening

Visual observations were made weekly on the condition of the plants. The date was recorded when the plants in a plot showed severe wilting. At the end of the experiment (60 DAP) the number of dead plants per plot were also counted and recorded. The number of days to severe wilting was then calculated. Data analysis for tolerance parameters such as number of days to death and number of dead plants were performed with [15] and included an analysis of variance (ANOVA) to obtain mean values, and the student's protected t-LSD test was calculated at the 0.01 probability level. The multiple t-distribution test procedure [16] was performed to group the lines as sensitive, intermediate or tolerant to drought stress.

2.3.2. Field Experiment

Data were collected on two plants at the middle rows at 42 days after planting (DAP), 84 DAP and 120 DAP and the following parameters were recorded and evaluated.

2.3.3. Plant Growth

Lengths of the shoots were measured using a meter tape and two plants were selected from each plot and meas-

Table 1. Sweetpotato accessions used for box screening and their characteristics.

No	Cultivar	Origin	Skin color	Flesh color	Storage root shape
1	Wit Blesbok	RSA	Copper	Dark cream	Obovate-Long elliptic
2	Lobed JIII	RSA	Purple	Cream	Long irregular
3	TO-1-1-B	RSA	Purple	Cream	Long irregular-Long oblong
4	Malavuwe III VM-5B	RSA	Purple	White	Long oblong
5	Hlabisa 4	RSA	Pink cream	White	Very long elliptic
6	3 Maande wit	RSA	White	White	Long irregular-Long oblong
7	6 Maande wit	RSA	White	White	Long irregular-Long oblong
8	Chingowa	Zambia	Cream	Cream	Long oblong-Long irregular
9	Xushu 18	Taiwan	Purple	White	Long elliptic-Oblong
10	Yan Shu 1	Taiwan	Pale purple	White	Heavy oblong
11	Atacama	Peru	Dark purple	White	Obovate-Round elliptic
12	Tacna	Peru	Copper	Pale yellow	Elliptic-Heavy elliptic
13	ST87.030	Peru	Pale light yellow	Light yellow	Round ell-Obovate
14	Zapallo	Peru	Pale orange	Orange cream	Round
15	Japon Tresmesino Selecto	Peru	Pink, cream	Orange cream	Ovate-Round
16	Jewel	USA	Orange brown	Orange	Long oblong
17	Cemsa 74-228	Cuba	Cream	Cream	Long oblong-Long irregular
18	Tanzania	Uganda	Cream	White	Long oblong-Long irregular
19	Toquecita	Puerto Rico	Cream	Cream	Long oblong-Long irregular
20	2004-3-8	ARC	Yellow orange	Orange	Obovate-Elliptic
21	2004-3-9	ARC	Purple	Pale orange	Obovate-Elliptic
22	2004-5-2	ARC	Yellow orange	Orange	Elliptic-Obovate
23	2004-9-1	USA	Purple	Orange	Elliptic-Long elliptic
24	2004-9-2	USA	Pink purple	Orange	Round elliptic-Short oblong
25	2004-9-5	USA	Pale red pink	Dark orange	Elliptic-Obovate
26	2004-10-1	ARC	Purple pink	Dark orange	Obovate-Elliptic
27	2004-11-8	ARC	Bright pink red	Dark orange	Elliptic-Round elliptic
28	2004-14-5	ARC	Yellow orange	Dark orange	Obovate-Elliptic
29	2004-16-1	ARC	Bright purple	Orange	Round elliptic-Obovate
30	2004-17-5	ARC	Dark purple red	Very dark orange	Elliptic-Obovate
31	2004-17-8	ARC	Orange	Dark orange	Obovate-Elliptic
32	Bosbok	ARC	Purple	White	Oblong-Long Oblong
33	Ndou	ARC	Dark cream	Dark cream	Round elliptic-Long elliptic
34	W-119	USA	Pink purple	Orange	Long elliptic-Long irregular
35	1999-1-3	ARC	Pale orange	Pale orange	Round elliptic
36	1999-9-4	ARC	White	White	Round
37	Hernandez	USA	Orange brown	Dark orange	Oblong
38	Impilo	ARC	Cream orange	Pale orange	Round elliptic
39	2000-3-1	ARC	Cream-white	Cream	Long elliptic-Obovate

Continued

40	1999-3-1	ARC	Pink copper-pale purple	Dark cream	Long elliptic-Round elliptic
41	2000-10-7	ARC	Pale pink	Orange	Obovate-Round elliptic
42	2001-5-2	ARC	Dark purple	Dark orange	Oblong-Long irregular
43	2002-21-1	ARC	Orange	Orange	Round elliptic-Obovate
44	2003-11-3	ARC	Pale orange	Dark orange	Obovate-Elliptic
45	2003-20-1	ARC	Cream orange	Dark orange	Elliptic-Obovate
46	2003-23-6	ARC	Dark purple red	Dark orange	Obovate-Elliptic
47	2002-24-2	ARC	Pale orange	Dark orange	Elliptic-Round elliptic
48	Khano	ARC	Pale red purple	Dark orange	Long elliptic
49	Phala	ARC	Purple	Cream	Oblong
50	Amasi	ARC	Cream brown	Cream orange	Oblong

ured with the meter tape and the lengths of the shoots were recorded.

2.3.4. Dry Matter Content

Plants were harvested and the fresh weight of both the roots and the shoots were taken separately using a measuring scale. The fresh roots were washed of soil particles and weighed for fresh weight and then cut into pieces and put in a labeled envelope and then oven-dried at 72˚C for 24h00 to get the dry weight. The shoots were placed in a labeled envelope and oven-dried at 40˚C for 24h00 to get the dry weight. The weights were recorded in a data sheet. The dry matter was calculated as follows:

$$\text{Dry matter \%} = \left[\left(\text{Fresh weight} - \text{dry weight}\right)/\text{Fresh weight}\right] \times 100$$

2.3.5. Canopy Temperature

Recordings of the temperature of the canopy were done in the early hours of the morning using an infra-red thermometer (Raytek Raynger ST20). This was taken at 1 m from the plot edge and 50 cm above the canopy, focusing on the leaves only to reflect exact reading.

2.3.6. Yield

The storage roots of the whole plot were harvested at 120 DAP. The storage roots were thereafter graded into marketable, unmarketable based on their shapes, sizes, weights and defects. Marketable roots were greater than 100 g with a diameter of 3 cm and above when measured and no noticeable pest attack or diseases. Unmarketable roots those less than 100 g and the diameter is less than 3 cm and those showing defects (cracks, irregular shape) and pest infestation.

2.4. Data Analysis

Data collected were subjected to statistical analysis using computer software [17]. Analysis of variance (ANOVA) was computed and means were compared by the least significance difference at 1% probability level.

3. Results and Discussion

3.1. Drought Response during Pre-Screening

The results of the pre-screening trial are shown in **Table 2**. The entries survived between 46 and 60 days before dying. The mean number of days to death was 56.44. The accession with the shortest days to wilting was Yan Shu1 (46.57) and those with the longest day to wilting were Atacama and 2004-16-1 (60.00). Most of the accessions started wilting at 57 days when the experiment was almost concluded indicating that the accessions are generally tolerant to water stress. According to [18], the physiological responses of plants to a deficit of water include leaf wilting, a reduction in leaf area, leaf abscission, and the stimulation of root growth by directing nu-

Table 2. Result of plastic box screening experiment.

Nr	Line/Variety*	DTD	SD	Group	Nr	Line/Variety	No Dead	SD	Group
11	Atacama	60.00	0.0	T	11	Atacama	0.00	0.00	T
29	2004-16-1	60.00	0.0	T	29	2004-16-1	0.00	0.00	T
22	2004-5-2	59.50	0.8	T	22	2004-5-2	0.50	0.84	T
15	Japon Tres	59.17	2.0	T	15	Japon Tres	0.83	2.04	T
24	2004-9-2	59.17	2.0	T	24	2004-9-2	0.83	2.04	T
35	1999-1-3	59.17	2.0	T	34	W-119	0.83	2.04	T
47	2003-24-2	59.03	1.9	T	35	1999-1-3	0.83	2.04	T
12	Tacna	59.00	2.0	T	47	2003-24-2	0.83	1.33	T
42	2001-5-2	59.00	2.0	T	12	Tacna	1.00	2.00	T
20	2004-3-8	58.70	2.1	T	20	2004-3-8	1.00	2.00	T
23	2004-9-1	58.70	2.1	T	23	2004-9-1	1.00	2.00	T
38	Impilo	58.67	2.0	T	42	2001-5-2	1.00	2.00	T
14	Zapallo	58.53	2.3	T	14	Zapallo	1.17	2.04	I
40	1999-3-1	58.33	2.6	T	38	Impilo	1.33	1.97	I
34	W-119	58.17	4.5	T	19	Toquecita	1.50	1.87	I
41	2000-10-7	58.03	3.1	T	13	ST87.030	1.67	2.58	I
13	ST87.030	57.73	3.7	T	40	1999-3-1	1.67	2.58	I
+C	Lethlabula	57.72	-	T	41	2000-10-7	1.67	2.58	I
2	Lobed JIII	57.67	2.3	T	+C	Lethlabula	1.80	-	I
48	Khano	57.62	2.9	T	28	2004-14-5	2.00	2.45	I
8	Chingovwa	57.50	2.7	T	48	Khano	2.00	2.45	I
16	Jewel	57.50	2.7	T	49	Phala	2.00	2.45	I
19	Toquecita	57.50	2.2	T	39	2000-3-1	2.17	2.32	I
21	2004-3-9	57.50	2.7	T	2	Lobed JIII	2.33	2.34	I
28	2004-14-5	57.50	3.3	T	33	Ndou	2.33	2.58	I
32	Bosbok	57.50	2.7	T	8	Chingovwa	2.50	2.74	I
36	1999-9-4	57.40	2.5	T	16	Jewel	2.50	2.74	I
39	2000-3-1	57.33	2.3	T	21	2004-3-9	2.50	2.74	I
49	Phala	57.20	3.4	T	27	2004-11-8	2.50	2.74	I
50	Amasi	56.53	2.0	T	32	Bosbok	2.50	2.74	I
45	2003-20-1	56.40	2.9	T	37	Hernandez	2.50	2.74	I
46	2003-23-6	56.33	2.0	T	−C	Resisto	2.55	-	I
33	Ndou	56.17	5.5	T	36	1999-9-4	2.60	2.51	I
27	2004-11-8	56.10	4.4	T	50	Amasi	2.83	2.40	I
−C	Resisto	56.10	-	T	44	2003-11-3	3.00	2.28	I
25	2004-9-5	55.77	3.9	T	45	2003-20-1	3.00	2.45	I
44	2003-11-3	55.50	3.3	T	46	2003-23-6	3.17	2.23	S
37	Hernandez	55.00	7.7	T	1	Wit Blesbok	3.33	2.58	S

Continued

9	Xushu 18	54.97	2.5	T	7	6 Maande wit	3.33	1.86	S
18	Tanzania	54.37	6.2	T	17	Cemsa 74-228	3.33	1.63	S
3	TO-1-1-B	54.33	3.4	T	18	Tanzania	3.33	2.58	S
7	6 Maande wit	53.77	3.0	T	25	2004-9-5	3.33	2.58	S
1	Wit Blesbok	53.69	6.4	T	5	Hlabisa 4	3.50	2.07	S
26	2004-10-1	53.63	4.1	T	3	TO-1-1-B	3.67	2.16	S
17	Cemsa 74-228	52.57	5.7	I	26	2004-10-1	3.67	1.75	S
5	Hlabisa 4	52.00	5.2	S	31	2004-17-8	3.67	1.51	S
6	3 Maande wit	51.58	4.7	S	6	3 Maande wit	3.79	1.60	S
31	2004-17-8	50.43	6.1	S	4	Malavuwe III VM-5B	3.83	1.47	S
4	Malavuwe III VM-5B	49.00	6.2	S	10	Yan Shu 1	4.25	1.17	S
10	Yan Shu 1	46.57	3.8	S	9	Xushu 18	4.33	1.21	S
Mean		56.44				Mean	2.23		
	Probability	<0.001				Probability	<0.001		
SEM		1.32			SEM		0.76		
LSD		4.88			LSD		2.12		
CV%		5.8			CV%		83.7		

*2002-21-1 and 2004-17-5 had poor vine material and did not establish well, no data collected; DTD = Days to Death, S = Sensitive, I = Intermediate, T = Tolerance, SD = Standard Deviation, −Control = Negative, +Control = Positive, SEM = Standard Error of Means.

trients to the underground parts of the plants. Observations made on the number of dead plants after the experiment were a better measure to discriminate the entries in terms of drought response. The least number of dead plants were found in Atacama and 2004-16-1, namely zero. In contrast entries at the bottom of the table had lost 4 plants during drought stress and were very sensitive to drought stress. The best performing accessions that were selected for field trials had potential drought tolerance capabilities which allow them to still flourish under prolong water stress. In addition, imported varieties which performed well in similar pre-screening experiments were also selected. It is expected that these accessions will also show acceptable yield when subjected to periodic moisture stress under field condition.

Success in breeding for drought tolerance has not been as pronounced as for many other traits. This is partly due to lack of simple, cheap, and reliable screening methods to select drought-tolerant plants and progenies from the segregating populations and partly due to the complexity of factors involved in drought tolerance. [19] described a simple wooden box pre-screening method showing good correlation with drought tolerance at vegetative and reproductive stages, to select drought-tolerant plants at the seedling stage. Several experiments on drought screening under greenhouse conditions have also been reported in many crops [20]-[24]. Wooden box seedling screening is suitable screening large numbers of accessions. It is essential in its ability to determine stress at developmental stages. [19] applied this method in screening large number of cowpea accessions. The parameters used for evaluation were moisture content, flowering, yield and wilting point.

The wooden box method was recommended because it is simple and non-destructive and it can easily be used to screen large number of accessions. In previous experiments, accessions were screened for drought in rain-out shelters [25]. Drought tolerance was measured in terms of yield reduction and drought sensitivity index (DSI) of [26]. The results of the screening in plastic boxes and planting on the field indicated a relation between number of days to wilting and DSI. These results therefore show that the boxes method is quick, simple and reliable and can be very effective especially for screening large number of accessions. [27] also conducted experiments in rainout shelters on sweetpotato to determine the effect of prolonged restriction of water on yield; accessions were planted in a rain out shelter and irrigated using different water regimes. It was concluded that there was a significant reduction in marketable storage yield with the best yield coming from the accessions supplied with higher volume of water. In general *in vitro* screening method proves to be an ideal method to screen large set of germplasm with less effort, accurately and the growth pattern differences are due to accessions with least environmental factor.

3.2. Drought Effect on Growth and Development

There were significant differences among the accessions in respect to canopy temperature at 42 DAP. The highest mean canopy temperature was found in W-119 with an average of 27.24˚C while the lowest of 20.62˚C was recorded in 2003-24-2 (**Table 3**). These figures are quite low and attest to the drought tolerant capabilities of these accessions. A lower canopy temperature in a drought stressed plant indicate a better capacity for taking up soil moisture and for maintaining better plant water status [28]. [29] used canopy temperature of drought stressed wheat accessions to characterize yield stability under various moisture conditions. A positive correlation was found between a DSI and canopy temperature in a stressed environment. Infrared canopy temperature provides an efficient method for rapid non-destructive monitoring of plant response to water stress. The average stem length of 38 cm which is the longest was recorded in Zapallo while the shortest was found in 2004-5-2 with a length of 28.6 cm. [30] 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%. Internode diameter was reduced by 12% to 50% across the accessions. Ejumula had the highest number of leaves with a mean value of 37.4 while the least mean value was found in both Phala and 2004-16-1.

The severity of the stress condition became intense at 84 DAP (**Table 4**). There were also little or no differences in the responses of the accessions to the canopy temperature at that stage and the lowest temperature of 13.5˚C was recorded in 2004-9-2 while the highest was recorded in Ndou (17.8˚C). There was however a significant difference among the accessions in the stem lengths. The longest length of 40 cm was recorded in both Tacna and Ndou while the lowest length was found in 2004-5-2. The highest mean values for number of leaves were recorded in Zapallo (40.00), the lowest value of 22 was found in 2004-5-2. According to [31], drought stress significantly decreases Relative Water Content (RWC) and has a strong effect on photosynthetic rate and this also leads to increase in leaf and canopy temperature. For 42 DAP the highest root dry matter percentage was recorded in W-119 with a value of 23.09%, Ejumula followed with 22.94% (**Table 3**). The rest of the accessions did have a dry matter percentage ranging between 15 and 20 percent. There was a significant difference

Table 3. Growth parameters collected at 42 DAP.

S/N	Cultivar	Canopy temperature (˚C)	Root dry matter (%)	Shoot dry matter (%)	Number of leaves (count)	Stem length (cm)
1	Tacna	22.62	19.83	17.94	28.20	31.40
2	Zapallo	21.50	17.07	15.80	32.80	38.80
3	Ndou	22.02	20.99	19.10	29.00	31.20
4	Phala	24.08	16.10	19.27	16.60	28.80
5	Ejumula	22.66	22.94	19.33	37.40	37.40
6	1999-3-1	21.24	21.93	25.63	21.00	31.60
7	W-119	27.24	23.09	23.06	30.80	32.80
8	2003-24-2	20.62	18.82	21.97	22.60	29.60
9	2004-16-1	25.26	19.20	20.47	16.60	34.40
10	2004-5-2	24.64	15.86	14.17	18.80	28.60
11	2004-9-2	22.76	18.08	15.73	23.20	30.40
12	Resisto	21.02	18.42	24.37	18.20	30.00
	MS	19.61	30.13	63.31	23.78	53.18
	Grand mean	22.97	19.36	19.47	24.6	32.08
	CV%	22.97	16.70	17.14	24.6	32.08
	LSD	5.981	4.188	4.314	10.160	6.464

Table 4. Growth parameters collected at 84 DAP.

S/N	Cultivar	Canopy temperature (˚C)	Root dry matter (%)	Shoot dry matter (%)	Number of leaves (count)	Stem length (cm)
1	Tacna	16.80	31.08	27.81	36	40
2	Zapallo	16.50	49.09	39.31	40	39
3	Ndou	17.80	56.85	41.79	28	40
4	Phala	17.40	43.71	40.01	25	38
5	Ejumula	16.60	44.31	37.32	36	38
6	1999-3-1	16.00	44.42	31.14	26	29
7	W-119	16.20	46.45	46.41	36	35
8	2003-24-2	17.60	46.48	29.62	24	37
9	2004-16-1	15.50	38.52	57.72	23	33
10	2004-5-2	16.30	59.39	44.66	22	25
11	2004-9-2	13.50	37.92	54.13	30	33
12	Resisto	16.00	60.90	67.08	26	42
	MS	2.94 ns	394.59 ns	700.46 ns	187.24 ns	122.15 ns
	Grand mean	16.51	46.96	43.08	29.26	33.75
	CV (%)	10.60	36.60	8.51	36.11	21.32
	LSD	2.441	21.776	4.672	13.471	9.712

among the accessions in the percentage shoot dry matter, the highest was recorded in 1999-3-1 having 25.63% and it was closely followed by W-119 and 2004-9-2 with 15.75%. The lowest percentage shoot dry matter of 14.17% was recorded in 2004-5-2. There was a general reduction in the root dry matter in all the accessions under water stress conditions. [32] indicated that storage root drymass is correlated positively with vegetative growth. Similarly, [11] reported a reduction in root dry mass under stress conditions. [11] 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 [33].

Despite the severity of the stress, some accessions still showed good traits reflecting in their dry matter accumulation at 84 DAP. The highest root dry matter of 60.90% was recorded in Resisto and this was followed by 2004-5-2 (59.39%) and Ndou (56.85%) (**Table 4**). Most of the rest of the accessions had mean values ranging between 37% to 49% with the lowest of 31.08 recorded in Tacna. Equally, Resisto had the highest shoot dry matter and the lowest was found in Tacna.

Observations made at 120DAP indicated that the accessions were matured for harvesting as they all showed signs of stress with most of the plant already wilting (**Table 5**). There was no significant difference in the canopy temperature among the accessions. 2004-9-2 has the lowest canopy temperature of 26.2˚C while the highest canopy temperature of 30˚C - 33˚C were found in W-119, 2003-24-2, 2004-16-1 and 2004-5-2. There was a noticeable difference in the stem length among the accessions; the longest stem length of 50 cm was recorded in Resisto while the shortest length of 27.0 cm was found in W-119. The highest number of leaves was found in Zapallo (60.6) while the lowest number was recorded in 2004-16-1 (14.8).

At 120 DAP Ejumula had the highest root dry matter percentage of 37.49% followed by Phala (37.49%). The lowest of 23.68% was found in 1999-3-1. Other accessions performed well having values ranging between 23 to 37% (**Table 5**).

3.3. Drought Effect on Root Yield

Water stress is a common phenomenon and it severely reduces yields of field crops grown under rain fed conditions [34]. The marketable yield in the present study ranged from 0.58 $t\cdot ha^{-1}$ to 3.83 $t\cdot ha^{-1}$ (**Table 6**). The highest marketable yield was recorded in Zapallo (3.83 $t\cdot ha^{-1}$), Tacna (3.63 $t\cdot ha^{-1}$) and Ndou (3.12 $t\cdot ha^{-1}$). The low-

Table 5. Data collected at 120 DAP (at harvest).

S/N	Cultivar	Canopy temperature (˚C)	Root dry matter (%)	Shoot dry matter (%)	Number of leaves (count)	Stem length (cm)
1	Tacna	28.34	28.09	31.20	48.60	47.80
2	Zapallo	29.24	33.90	33.49	60.60	41.00
3	Ndou	26.84	34.38	31.89	30.20	38.20
4	Phala	27.12	37.49	37.79	44.60	50.40
5	Ejumula	26.90	37.73	35.41	30.00	40.40
6	1999-3-1	26.78	23.68	28.11	25.00	36.80
7	W-119	31.34	28.72	34.01	28.80	27.00
8	2003-24-2	32.62	35.51	31.10	26.40	40.00
9	2004-16-1	30.08	25.50	36.15	14.80	30.60
10	2004-5-2	30.52	24.55	29.67	18.20	30.40
11	2004-9-2	26.24	28.43	32.20	25.40	40.60
12	Resisto	27.96	31.83	43.65	36.20	50.00
	MS	21.564 ns	124.43 ns	97.28 ns	861.67 ns	286.212 ns
	Grand mean	28.67	30.81	33.47	23.40	39.43
	CV (%)	16.36	15.71	32.09	54.30	38.49
	LSD	5.976	6.172	13.692	22.442	19.344

Table 6. Yield data collected at harvest at 120 DAP.

S/N	Cultivar	MYLD (t/ha)	T-YLD (t/ha)	Survival rate (%)	Root dry matter (%)
1	Tacna	3.63	9.24	81.66	28.23
2	Zapallo	3.83	6.16	77.49	33.49
3	Ndou	3.12	4.50	75.00	31.89
4	Phala	1.05	1.91	59.99	37.79
5	Ejumula	2.31	3.81	75.83	35.41
6	1999-3-1	1.83	3.00	81.66	28.11
7	W-119	1.83	3.23	77.50	34.01
8	2003-24-2	0.58	1.97	64.16	31.10
9	2004-16-1	1.31	2.18	68.33	36.15
10	2004-5-2	0.96	1.69	53.33	29.67
11	2004-9-2	2.02	5.58	66.66	32.20
12	Resisto	1.23	2.31	59.16	43.65
	MS	5.67	25.48	448.54	97.28 ns
	Grand mean	1.979	3.801	70.069	33.470
	CV (%)	31.30	28.48	16.70	32.09
	LSD	0.789	1.379	14.918	13.692

est marketable yield of 0.58 $t \cdot ha^{-1}$ was found in 2003-24-2. The ANOVA showed that there were significant differences among the accessions. Also, the three accessions with the highest marketable yield mostly had the highest total yield. The highest total yield was recorded in Tacna (9.24 $t \cdot ha^{-1}$), Zapallo (6.16 $t \cdot ha^{-1}$) and

2004-9-2 (5.58 t·ha^{-1}). These yield values were comparable to the average yield values of 5-10 t·ha^{-1} normally recorded for sweetpotato grown under subsistence farming under rain-fed conditions. The lowest yield was recorded in 2004-5-2 (1.69 t·ha^{-1}). This result is also consistent with the observations of [30] [27] on yield of sweetpotato accessions subjected to prolonged restriction of water.

3.4. Drought Effect on Survival Rates

Accessions Tacna and 1999-3-1 had the highest survival rate (**Table 6**) of 81.66% followed by W-119 (77.50%) Zapallo (77.49%), Ejumula (75.83%) and Ndou (75.0%). This result was an indication that these accessions had a very good mechanism to tolerate water stress. The lowest was found in 2004-5-2 (53.33%). It is therefore evident that yield and growth parameters such as leaf growth, dry biomass, root dry weight and internodes length can be used to successfully determine drought tolerant accessions in sweetpotato. In addition, [27] found a reduction in photosynthetic rate, stomatal conductance and expansion of leaf canopy related to reduction in yield of sweetpotato.

4. Conclusion

Among the 50 accessions pre-screened for drought 12 accessions were found to be drought tolerant based on the number of days to wilting. The accessions include Tacna, Zapallo, 2004-9-2, Ndou, 2004-16-1, 2003-24-2, Resisto, W-119, Ejumula, Phala, 2004-5-2, 1999-3-1. These 12 pre-screened accessions were further evaluated in field trials and five accessions (Tacna, Zapallo, 2004-9-2, Ndou and Ejumula) were considered to have the greatest tolerance to water stress. Based on the above findings, these five best performing accessions were therefore recommended to be included as parents in the drought tolerant sweetpotato breeding program.

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