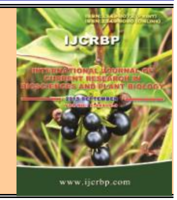
Int. J. Curr. Res. Biosci. Plant Biol. 2015, 2(9): 104-114

EXCELLENT PUBLISHERS

International Journal of Current Research in Biosciences and Plant Biology

ISSN: 2349-8080 Volume 2 Number 9 (September-2015) pp. 104-114

www.ijcrbp.com



Original Research Article

Evaluation of Selected Sweetpotato Genotypes for Drought Resistance under Greenhouse Condition

Agnes C. Perey*

Tarlac College of Agriculture, Institute of Agriculture and Forestry, Camiling, Tarlac, Philippines

**Corresponding author.*

Abstract

Sweetpotato is a moderately drought tolerant crop, however, its production is still constrained by drought which is currently a worldwide problem limiting crop production. The study aimed to screen sweetpotato genotypes from various germplasm sources for drought resistance, determine the effect of water stress on the growth and yield of the genotypes, evaluate the growth and yield of selected sweetpotato genotypes for drought resistance under greenhouse condition, and determine the interaction effect of sweetpotato genotypes and levels of water stress. The ten sweetpotato genotypes were evaluated for drought resistance under greenhouse condition. Genotype Inubi-CA exhibited the lowest drought score and highest recovery rating. It also produced the longest vines at 70 and 105 DAP, highest leaf area index at 35 DAP, heaviest vines and most number of vine cuttings. Out of the 10 genotypes, five genotypes (JOG 11-10, JK 18 - 4, Taiwan D, NSIC 23 and Inubi-CA) were observed to have the characters for stress resistance such as small leaf area and leaf area index, long roots, low drought score, high recovery rating and more vine yield. Leaf area at 65 DAP and root weight was positively correlated with vine yield. Conversely, drought score was negatively correlated with vine yield.

Keywords

Drought resistance

Genotypes

Greenhouse

Ipomoea batatas

Introduction

Sweet potato (*Ipomoea batatas* L. Lam), is considered worldwide as an indigenous, traditional and subsistence crop. In the Philippines, it is popularly known as "camote", a versatile root-crop, rich in carbohydrates and other nutrients. Its roots can be boiled, fried, sweetened, processed into flour for cakes and as part of feed formulation. Its soft shoots can be prepared as vegetable salad while the hard stem can be used as feed for pigs, goats and other animals (Laranang et al., 2004).

Sweetpotato is a secondary staple food crop for people living in rural areas, hilly regions and coastal plains. In Tarlac, sweetpotato is next to rice. Production of quality storage roots of sweetpotato is important to sustain the emerging population in the area. However, farmers had difficulties in producing quality storage roots during summer due to production constrains such as genotypes, water and temperature.

Sweet potato productivity is limited by a number of both biotic and abiotic constraints. Water stress is one of the most common environmental stresses affecting plant growth and productivity (Boyer, 1982). Plant water stress, often times caused by drought, can have major impacts on plant growth and development. When it comes to crops, plant water stress can be the cause of lower yields and possible crop failure (Onyilagha, 2008).

The main consequence of moisture stress is decreased growth and development caused by reduced photosynthesis. Photosynthesis is the process in which plants combine water, carbon dioxide and light to make carbohydrates for energy. Chemical limitations due to reductions in critical photosynthetic components such as water can negatively impact plant growth (Farkas, 2004).

Low water availability can also cause physical limitations in plants. Stomata are plant cells that control movement of water, carbon dioxide, and oxygen into and out of the plant. During moisture stress, stomata close to conserve water. This also closes the pathway for the exchange of water, carbon dioxide, and oxygen resulting in decreases in photosynthesis. Leaf growth will be affected by moisture stress more than root growth because roots are more able to compensate for moisture stress (Bauder, 2009).

Drought is a worldwide problem, seriously limiting global crop production. Recently, global climate change has made this situation more serious (Pan, 2002). Drought is a complex physical-chemical process, in which many biological macromolecules and small molecules are involved, such as nucleic acids (DNA, RNA, micro RNA), proteins, carbohydrates, lipids, hormones, ions, free radicals and mineral elements (Levitt, 1979). Sweet potato is considered to be moderately drought tolerant (Valenzuela et al., 2000). However, drought is often a major environmental constraint for sweetpotato production in areas where it is grown under rainfed condition (Anselmo et al., 1998).

This study was conducted to screen and evaluate sweetpotato genotypes for water stress. To evaluate the growth and yield of selected sweetpotato genotypes for drought resistance under greenhouse condition; To determine the interaction effect of sweetpotato genotypes and levels of water stress; and to correlate growth parameters with vine yield of sweetpotato genotypes.

Materials and methods

The 10 selected sweetpotato genotypes were used to evaluate for drought resistance under greenhouse condition. The characteristics of the 10 sweetpotato genotypes considered drought resistant are presented in Table 1.

Table 1. Ten (10) selected genotypes with their morphological, physiological and growth characteristics.

Genotype	Leaf area (cm^2)	Drought score*	Relative water content (%)	No. of roots	Length of roots (cm)
BSU # 1	23.97	1.00	31.48	17.00	8.30
JK 7-4	56.78	1.00	28.92	12.00	7.97
JK 18 -4	23.97	1.00	27.43	11.00	8.18
JK 23 -1	32.17	1.00	20.68	9.00	8.81
JOG 11-10	20.19	1.00	33.96	19.67	7.86
MBE-SP	92.74	1.00	43.73	8.00	10.27
NSIC- 23	32.80	1.00	32.35	10.00	7.44
NSIC- 31	101.57	1.67	29.60	7.33	5.24
Taiwan -D	26.50	1.00	30.55	9.00	7.34
UBE- CA	34.07	1.00	29.19	10.0	8.28

* Rating scale: 1-no stress; 3-30% of the leaves wilted; 5- 50% of the leaves wilted; 7- 80% of the leaves wilted ; 9 – complete wilting;

Experimental design and treatments

The 10×3 factor factorial in randomized complete block design (RCBD) was used replicated three times with 10 samples plants per treatment. The 10 genotypes presented in Table 1 were assigned as Factor A and three levels of water stress were assigned as Factor B as follows:

Factor A – Sweetpotato Genotypes

Factor B – Level water stress

- L_1 – Control /normal (20 cb)
- L_2 – Moderate stress (60 cb)
- L_3 – Severe stress (80 cb)

Crop establishment

Plantlets of selected genotypes were planted in 8×8×14 inches polyethylene bag. Polyethylene bags were filled with 12 kg mixture of three parts of sandy loam soil (sterilized) and one half part vermicompost. Plantlets were irrigated after planting. To ensure growth and development of the crops, fertilization was done using complete fertilizer (14 N -14 P_20_5-14 K_20) at 15 g per pot in split application where 5 g was applied at planting and 10 g after one month planting.

Drought imposition

All treatment combinations were watered regularly and evenly with two liters of water per pot for four weeks until the crops were established. From the initial reading of 20 cb (normal), watering was withheld until SMP was dropped to 60 cb and 80 cb then watering was done; to attain (60 cb and 80 cb) 1500 ml and 2100 ml of water, respectively, were added. The procedure was repeated for several times up to one week before harvesting.

Control of insect pest and diseases

Spraying of pesticide was done once a week. Hand weeding was done every two weeks.

Statistical analysis

All data were tabulated and analyzed using the appropriate analysis of variance for two factor factorial in Randomized Complete Block Design. Significance among treatment means was analyzed using the Duncan's Multiple Range Test (DMRT). Correlation analysis was also done. The degree of relationship between two variables was measures using the Pearson product moment correlation coefficient (R) which characterizes the independence of X and Y.

Results and discussion

Meteorological data

The greenhouse air temperature during the growing period ranged from 19°C to 43°C. The highest temperature was observed in July with 43°C, while the lowest air temperature was observed in October with 18°C. The high temperature of 43°C recorded was beyond the temperature requirement of sweetpotato. According to Romero et al. (1991), sweetpotato plants grow with temperatures between 15°C and 35°C and that lower and higher temperatures have detrimental effects on yield. This condition may explain the absence of storage roots of the genotypes evaluated in this study.

Morphological parameters

Leaf characters

Leaf orientation: Most of the genotypes exhibited planophyle leaf orientation while genotype JK-23-1 had erectophyle leaf orientation. Erectophyle leaf orientation was noted to be efficient in intercepting solar radiation.

Leaf reaction to moisture deficit: Leaves of all genotypes responded to water deficit through shedding and dropping. This conforms with the study of Noggle and Fritz (1983) that drooping and sagging of plant tissues especially leaves known as wilting which is due to change in elastic properties of cell walls when turgor pressure declines below a certain critical value. The leaves of some herbaceous plants sometimes droop and sag in the afternoon during hot weather and recover again at night.

Physiological parameters

Drought score: Significant differences were observed on the drought scores of the different genotypes. Genotype Inubi –CA registered the lowest drought score (2.33) followed by genotypes Taiwan D, NSIC 31, and BSU # 1 with 2.56 drought score. These genotypes have comparable drought score with Inubi – CA. Low drought score may be attributed to mechanism that help in absorbing sufficient water to maintain leaf turgidity during water stress condition. One mechanism could be the production of pubescence in the leaves which was exhibited by Inubi – CA (Table 2).

Significant difference was observed on the drought score of the plants as affected by the level of water stress. Genotypes under severe stress (80 cb) exhibited the highest drought score of 5.87. Genotypes under moderate stress condition had comparable drought score (3.20) with plants under normal condition (1.33). It was also observed that plants in the normal condition or sufficient water showed wilting of leaves. This could be attributed to the high temperature (39-43°C) inside the greenhouse. Genotypes and level of water stress interacted significantly to affect drought scores Genotypes under normal condition (20 cb) had the lowest score ranging from 1.00 and 1.67 (Table 2). High drought score is due to the depletion of water needed for turgidity brought about by water stress and high temperature during conduct of the study.

Table 2. Drought score as affected by sweetpotato genotypes and level of water stress under greenhouse condition.

Genotype	Drought score*			Mean
	Level of water stress			
	Control (20 cb)	Moderate (60 cb)	Severe (80 cb)	
BSU# 1	1.00 ^{a}	2.33 ^{cd}	4.33 ^{cd}	2.56 ^{bc}
JK-7-1	1.67 ^{a}	4.33 ^{b}	8.33 ^{a}	4.78 ^{ab}
JK-18-4	1.67 ^{a}	6.33 ^{a}	8.33 ^{a}	5.44 ^{a}
JK 23-1	1.00 ^{a}	3.67 ^{bc}	5.67 bc	3.44 ^{b}
JOG 11-10	1.67 ^{a}	4.33 ^{b}	6.33 ^{b}	4.11 ^{bc}
MBE-SP	1.67 ^{a}	2.33 ^{cd}	7.07 ^{ab}	3.69 ^{b}
NSIC 23	1.00 ^{a}	2.33 ^{cd}	6.33 b	3.22 ^{bc}
NSIC 31	1.00 ^{a}	2.33 ^{cd}	4.33 ^{cd}	2.56 ^{bc}
TAIWAN D	1.67 ^{a}	2.33 ^{cd}	3.67 ^{d}	2.56 ^{bc}
Inubi-CA	1.00 ^{a}	1.67 ^{d}	4.33 ^{cd}	2.33^{bc}
L-Mean	1.33 ^{bc}	3.20 ^{b}	5.87 ^{a}	3.47

*Rating scale: 1 = no stress; 3 = 30% of the leaves wilted; 5 = 50% of the leaves wilted; 7 = 80% of the leaves wilted; 9 = complete wilting and death of plants.

Recovery rating: There were significant differences on the recovery rating of the different genotypes (Table 3). Genotype Taiwan D had the highest recovery rating but not significantly different with Inubi-CA. Genotypes JK 7-4, JOG 11-10 and NSIC 31 were comparable with Taiwan D and Inubi- CA. The lowest recovery rating was noted from MBE –SP. This conforms with the work of Taligan and Tad-awan (2004) in potato that high recovery rating of cultivars results after rewatering under greenhouse condition.

Level of water stress significantly affected the recovery rating of the plants after rewatering. Genotypes under control condition (20 cb) had the highest recovery rating followed by genotypes under moderate stress condition (60 cb) and the lowest recovery rating was observed from genotypes under severe condition.

Significant interaction of genotypes and level of water stress was observed on the recovery rating. All genotypes under control condition (20 cb) and moderate stress condition (60 cb) had higher and comparable recovery ratings ranging from 5.00 to 9.00 and the lowest recovery rating was observed from genotypes under severe stress condition (60 cb). It was also observed that genotypes Taiwan D and Inubi–CA under severe stress condition (80 cb) had recovery ratings comparable with the control and moderate stress condition (Table 3). This could be attributed to the effect of genotypic characteristic of the plants and the responses to different levels of water stress. Sweetpotato as described by O'Sullivan (2002) is known as a relatively drought-tolerant crop, it will tolerate brief periods of drought stress, recovering quickly when soil moisture is restored.

Relative water content: Relative water content (RWC) of the different genotypes did not differ at 35 DAP. Highest RWC was obtained from genotypes JK- 23-1 while the lowest was observed from Inubi-CA. Other genotypes had RWC ranging from 36.93 to 55.36 %. This could be due to the mechanism of genotypes that can regain turgidity rapidly over other genotypes. According to Laure et al. (2009) plants were able to regain turgidity to certain extent and slowly loose moisture as the stress continued until harvest. No significant differences were observed among the levels of water stress on relative water content at 35 DAP. Results show no significant interaction of genotypes and level of water stress on RWC at 30 DAP.

Net assimilation rate: Net assimilation rate (NAR) of the different genotypes was greatly affected at 35, 50 and 65 DAP. NSIC 23 exhibited the highest NAR with a mean of 3.96% followed by JK-18-4 (3.89%) but not significantly different with NSIC 23. Genotype JOG 11-10 (3.69%) had comparable NAR with NSIC 23 and JK-18-4 (3.89). The lowest NAR was observed from genotype MBE-SP (3.27%). At 50 DAP, it was observed that most genotypes had an increased NAR except for genotype Inubi-CA (3.23%). Genotype JK 23-1 had the highest NAR with a mean of 4.93%

followed by JK 18-4 (4.89%), but these genotypes were not significantly different.

The NAR of all genotypes at 65 DAP had increased. Genotype JK 18-4 had the highest NAR (5.84%) which was not significantly different with JK 7-4 (5.79%). JOG 11-10 (5.46%), Inubi –CA (5.07%) and JK 23-1 (5.05%) had comparable NAR with JK18-4 (5.84%) and JK 7- 4 (5.79%), while the lowest NAR was observed from genotype BSU#1 with a mean of 3.32%. Results indicate that all genotypes had an increased dry weight accumulation per unit area of assimilate per unit of time.

According to Fitter and Hay (1981) net assimilation rate or the dry matter accumulation rate per unit leaf area is one of the useful parameters on growth analysis, which influence the increase in plant weight per unit area of assimilatory tissue (usually leaf area: A_L) per unit of time. It was observed that NAR of the genotypes increased as plants mature regardless of water stress level. Hunt (1978) mentioned that NAR is not constant with time but show downward drift with plant age, and the age drift is accelerated by unfavorable environment. Genotype and dry matter gain per unit leaf surface decreases as new leaves are added due to mutual shading. Also, NAR decreases at more than 50 days old leaves since photosynthesis decreases (Zaag, 1992).

Significant differences were noted on NAR of the plants at 35, 50 and 65 DAP as affected by level of water stress. NAR of all genotypes decreased with increasing water stress at 35, 50 and 65 DAP. Lowest NAR was observed from genotypes under severe stress with mean of 2.54%, 3.18% and 4.46% respectively. Based on the study of Van Heerden (2008), restricted water supply leads to inhibition of CO_2 assimilation and photosynthesis through stomatal closure. Further, drought stress decreased leaf area duration, cumulative water transpired, net assimilation rate (Simane et al., 1994). This may explain the decreasing trend in the net assimilation rates of sweetpotato with increasing water stress.

Most of the genotypes under moderate stress had an increased NAR except for genotype Inubi-CA which did not increase in NAR from 35 up to 50 DAP. Genotypes NSIC 31 and JOG 11-10 showed a decrease in NAR with from 35 to 50 DAP. The interaction of genotypes and level of water stress did not significantly affect the NAR at 35, 50 and 65 DAP.

Growth parameters

Plant vigor: Genotypes JOG 11-10, NSIC 23, NSIC 31, Unubi-CA, Taiwan D, JK 7-4 and MBE- SP exhibited highly vigorous growth. Genotypes JK 18- 4 and BSU # 1 had moderate vigor rates of 4.33 and 3.67 (less vigorous) respectively. Plant vigor at 30 DAP was not significantly affected by level of water stress. Genotypes and level of water stress did not significantly affect plant vigor at 30 DAP.

Vine length at 35 DAP: Vine length significantly varied at 35 DAP among the different genotypes. Genotype JK 7- 4 exhibited the longest vines (but not significantly different with genotypes JK 23-1, NSIC 23, BSU # 1, and Inubi- CA. The shortest vines were observed from JK 18-4. Vine length at 35 days was not significantly affected by the level of water stress. The interaction of genotypes and level of water stress did not significantly affect the vine length at 35 DAP.

Vine length at 70 and 105 DAP: Genotypes significantly varied in their vine length at 70 DAP. Genotype BSU # 1 exhibited the longest vines (260.83 cm) at 70 DAP followed by Inubi–CA with a mean of 259.86 cm. Genotypes JK 7-4 (250.47 cm), MBE –SP (256.88 cm), JK 23-1 (231.40 cm) and JOG 11-10 (228.86 cm) had comparable vine lengths with BSU #1 and Inubi –CA. The shortest vines were observed from genotype JK 18-4 with a mean of 162.64 cm. It also observed that all genotypes under different level of water stress had increased in vine length from 35 to 70 DAP. Vine length is primarily a genotypic characteristic (OSU, 1997), however, different genotypes have different sensitivity to the environment. For instance Taiwan D and JK 18-4 produce short vines with mean of 169.18 cm and 162.64 cm, respectively to conserve water, thus coping with water stress. Other genotypes like BSU #1 and Inubi-CA produce long vines 260.83 cm and 259.86 cm, respectively also a coping mechanism by more roots per node as the vine creeps on the ground.

At 105 DAP genotype Inubi- CA registered the longest vines but not significantly different with BSU #1 with mean of 391.80cm and 391.24 cm, respectively. Genotypes MBE-SP (308.16 cm), JOG 11-10 (305.84 cm), JK23-1 (302.73 cm) and JK 7-4 (322.51 cm) had comparable vine lengths with Inubi - CA and BSU # 1.

The adaptive mechanism of sweetpotato to drought condition includes vine length. The vines elongate with increasing moisture stress. According to Hammett et al. (1982), sweetpotatoes are considered moderately tolerant to drought conditions due to their low plant growth habit and extensive root system.

Vine length at 70 DAP was significantly affected by level of water stress. Genotypes under severe stress condition (60 cb) had the longest vines (240.97%) followed by genotypes under moderate stress condition (60 cb) (223.05cm), and the lowest vine length was observed from genotypes under control condition (20 cb) with a mean of 205.63 cm.

Vine length at 105 DAP was significantly affected by level of water stress. Genotypes under moderate stress (60 cb) had the longest vines 341.95 cm followed by genotypes under severe stress condition (60 cb) with a mean of 292.51 cm and the lowest vine length was observed from genotypes under control condition (20 cb) with a mean of 286.61cm. The interaction of genotypes and level of water stress did not significantly affect the vine length of the plant at 70 and 105 DAP.

Number of vine cuttings per plant: Number of vine per plant was significantly different among the genotypes. Genotype BSU # 1 had the most vines with a mean of 7.82 while the lowest vine number was observed from genotype Taiwan D with a mean of 3.96. The number of vine cuttings was significantly affected by level of water stress. Genotypes under moderate stress condition produced more number of vines with a mean of 6.83 than genotypes under normal condition with a mean of 5.72. Number of vine cuttings of plants as affected by the genotypes and level of water stress was not significant.

Vine weight per plant: Vine weight was significantly different among the genotypes. The highest vine yield was observed from genotype NSIC 31 followed by Inubi-CA with mean of 842.78 g and 714.44g, respectively. Lowest vine yield was observed from JK - 18-4 with a mean of 363.22g. Vine weight was significantly affected by level of water stress. Genotypes under moderate stress registered the heaviest vine compared to genotypes under normal condition and genotypes under severe stress condition with means of 648.17g, 545.60 g and 481.33 g, respectively.

Vine yield of plant as affected by genotypes and level of water stress was significant. Genotype NSIC 31 produced the heaviest vines under any level of water stress (845g, 928.33g and 755g) while the lowest was observed from genotype JK 18-4 (376.33g, 447.33g and 266.00g). Other treatment combinations had vine weights ranging from 376.33 to 845.00 g.

Leaf area: Significant differences were noted on the area per leaf of the different genotypes at 35, 50 and 65 DAP. Genotype BSU# 1 was noted to have the highest leaf area with a mean of 92.66 cm^2 at 35 DAP. Genotypes NSIC 23, Taiwan D, JK 23-1, JOG 11-10 and Inubi-CA with means of 84.04 cm^2, 83.76 cm^2, 77.20 $cm^{2,}$ 73.16 cm^2 and 71.81 cm^2, respectively had comparable leaf area with BSU #1. The lowest leaf area was observed from genotypes MBE-SP with a mean of 54.11 cm^2.

Genotypes BSU # 1 registered the highest leaf area but not significantly different with Inubi – CA with means of 265.96 cm^2 and 254.49 cm^2, respectively. Genotypes JK 7-4, JK 23-1, MBE-SP and JOG -11-10 with means of 232.56 cm^2, 220.51 cm^2 , 217.24 cm^2 and 217.11 cm^2, respectively were comparable with BSU #1 and Inubi-CA. The lowest leaf area was observed from genotypes Taiwan D with a mean of 134.31 cm^2. At 65 DAP genotype Inubi-CA with a mean of 310.56 cm^2 while the lowest leaf area was observed from JK 18-4 with a mean of 142.36 cm^2. Area per leaf at 35 and 50 DAP were not greatly affected by level of water stress.

Level of water stress significantly affected the area per leaf at 65 DAP. Leaf area of all genotypes under different levels of water stress increased. Genotypes under normal condition (20 cb) registered the highest leaf area followed by genotypes under moderate condition (60 cb) with means of 296.95 cm^2 and 260.15 cm^2, respectively while the lowest leaf area was observed from genotypes under severe stress condition (80 cb) with a mean of 235.91 cm^2.

Water deficit or insufficient water supply inhibits cell division and expansion resulting in the production of smaller leaves (Zaag, 1992; ICPRE and UI-CALS, 2002; Pritchard and Amthor, 2005). Area per leaf of genotypes at 35 and 65 DAP was not remarkably affected by the interaction of genotypes and level of water stress.

Leaf area index: Genotypes significantly differ in their leaf area index (LAI) at 35, 50 and 65 DAP. All genotypes used had an increase in LAI at 35, 50 up to 65 DAP having vigorous lateral shoots. Results show significant differences among genotypes for LAI. Genotypes BSU# 1 exhibited the largest LAI but comparable with JK-23-1 with means of 3.67 and 3.22, respectively. The smallest LAI was obtained from genotype JK-18-4 at 35 DAP with a mean of 1.44. This could be due to shedding of leaves and heavy infestation of cutworms.

At 50 DAP, BSU#1 had the highest leaf area index (9.14) while the lowest was from MBE-SP and Taiwan-D with means of 2.66 and 2.87, respectively at 50 and 65 DAP. LAI at 35 DAP was not significantly affected by level of water stress. At 50 and 65 DAP, highest LAI was observed from moderate water stress with means of 6.18 and 12.50, respectively. This shows that sweetpotato can tolerate moderate stress condition, as shown by normal leaf development. But at severe stress, leaf development is affected to an extent that leaf development is reduced. This could be attributed to the defense mechanism of having small leaves against water stress. As stated by Akyeampong (1985), drought-stressed leaves were smaller than the unstressed leaves in the case of cowpea. The interaction of genotypes and level of water stress did not significantly affect the LAI of plants at 35, 50 and 65 DAP.

Root weight at harvest: There were significant differences on the root weight at harvest of the different genotypes. Genotype NSIC 31 produced the heaviest root with a mean of 14.06g, while the lowest was observed from genotype JK 7-4 with a mean of 6.55g. Other genotypes had the root weight ranging from 4.92 to 12.61 g.

Root weight at harvest was significantly affected by level of water stress. Genotypes under severe stress condition (80 cb) registered the heaviest roots with a mean of 8.68g while the lowest was noted from genotypes under control and moderate stress with the same mean of 6.92g. This may be due to the mechanism of the plants of having long roots during stress. Akyeampong (1985) and Hall and Schulze (1980) found that in cowpea, increased root density and depth during stress to exploit larger volume of soil to ensure the survival of the crop during drought water stress and maintain plant status. Pritchard and Amthor (2005) stressed that water stress sometimes stimulates root growth and this presumably represents a mechanism to compensate for limited water supply. Moreover, adaptation allow maximum growth and reproduction during dry period which includes rapid development, C_4 photosynthesis, high cuticular and stomatal resistance to water loss, deep rooting systems, minimal leaf area, leaf rolling, flagging and self shading.

Genotypes and level of water stress interacted significantly to affect root. Genotype NSIC 31 under severe stress condition (60 cb) had the highest root weight with a mean of 15.45g while the lowest weight was observed from genotype JK 23-1 under normal condition (20 cb) with a mean of 4.77g.

Root length at harvest: There were significant differences on the root length of the different genotypes. Genotype JOG 11-10 exhibited the longest roots with a mean of 61.44cm while the shortest roots were obtained from NSIC 23 with a mean of 24.33cm. Length of roots at harvest was significantly affected by level of water stress. The longest roots were observed from genotypes under severe stress condition (60 cb), followed by moderate stress while the shortest roots were observed in genotypes under control condition (20 cb) with means of 46.33g, 37.73g and 34.7g, respectively.

Gurgel (2008) stated that indicators of drought tolerance is characterized by having a deep root system and ability of leaf rolling since root play an important role in controlling plant water status to avoid drought injury and leaves roll under dry conditions, exposing less leaf surface to be in contact with dry air, which was also observed during the study.

There was a significant interaction on the length of roots as affected by genotypes and level of water stress. The longest roots were observed from genotypes JK 7-4 under severe stress condition (60 cb) with a mean of 73.00cm while the shortest roots were observed from genotypes TAIWAN D under normal condition with a mean of 12.00cm. Other treatment combinations had root lengths ranging from 15.00 to 70.67 cm.

Incidence of insect pest and diseases

Cutworm incidence: Reaction to cutworm was significantly affected by different genotypes. Genotype JOG 11-10 had the lowest incidence with a mean of 1.44 but not significantly different with genotypes JK 7-4, MBE-SP and BSU # 1 with means of 1.56, 1.67 and 1.78, respectively. The highest cutworm incidence was observed from JK 23-1 with a mean of 3.89 (Table 4).

Incidence of cutworm was significantly affected by level of water stress. Genotypes under severe stress condition (60 cb) obtained the highest incidence rating of 2.73 followed by moderate stress condition and the lowest rating was observed from genotypes under control condition with means of 2.27 and 2.27, respectively. It was observed that plants that were stressed are more susceptible to cutworm infestation.

Genotypes and level of water stress interacted significantly with regards to incidence of cutworm. Genotype Inubi -CA under severe stress incurred the highest incidence with a mean of 4.33 while the lowest rating was observed from genotypes JK 7 -4, JOG 11-10, BSU # 1 and JK 18-4 under control condition with the same mean of 1.0 (Table 4).

Table 4. Cutworm incidence of the 10 selected sweetpotato genotypes as affected by level of water stress.

Genotype	Cutworm incidence*			G-Mean
	Level of water stress			
	Control (20 cb)	Moderate (60 cb)	Severe (80 cb)	
BSU# 1	1.00 [b]	2.00 [bcd]	2.33 [cde]	1.78 [bc]
JK-7-1	1.00 [b]	1.67 [cd]	2.00 [cde]	1.56 [bc]
JK-18-4	1.00 [b]	1.00 [d]	4.00 [ab]	2.00 [b]
JK 23-1	3.67 [a]	4.00 [a]	4.00 [ab]	3.89 [a]
JOG 11-10	1.00 [b]	1.67 [cd]	1.67 [de]	1.44 [bc]
MBE-SP	1.67 [b]	1.33 [d]	2.00 [cde]	1.67 [bc]
NSIC 23	3.33 [a]	3.33 [ab]	3.33 [abc]	3.33 [a]
NSIC 31	3.33 [a]	2.33 [bcd]	1.00 [e]	2.22 [b]
TAIWAN D	1.67 [b]	2.33 [bcd]	2.67 [bcd]	2.22 [b]
Inubi-CA	4.00 [a]	3.00 [abc]	4.33 [a]	3.78 [a]
L-Mean	2.17 [b]	2.27 [b]	2.73 [a]	2.39

* Rating scale: 1- no apparent injury; 2- injury confined to youngest leaf; 3- some older leaves injured; 4-over 50% of the leaves injured; 5- over 90% of the leaves injured.

Leaf curling: The highest disease rating was observed from genotype BSU#1 with a mean of 1.89 while genotypes JOG 11-10 and JK 18-7 had no disease symptoms observed with the same mean of 0.00. JK 23-1 was susceptible to leaf curling with a mean of 1.44 while JOG 11-10 and JK 18-4 were highly resistant to leaf curling disease with the same mean of 0.00. Incidence of leaf curl disease was not significantly affected by level of water stress. All genotypes under different level of stress had ratings of 0.47 to 0.60, where there is 0 to 2.5% infection. The interaction of genotypes and level of water stress did not significantly affect the incidence of viral disease. All genotypes under different levels of water stress had ratings ranging from 0.00 to 2.33 (Table 5).

Table 5. Leaf curling incidence of 10 selected sweetpotato genotypes as affected by level of water stress.

Genotype	Leaf curling incidence*			G-Mean
	Level of water stress			
	Control (20 cb)	Moderate (60 cb)	Severe (80 cb)	
BSU# 1	1.33	2.00	2.33	1.89 [a]
JK-7-1	0.67	0.33	0.33	0.44 [bc]
JK-18-4	0.00	0.00	0.00	0.00 [c]
JK 23-1	1.00	1.67	1.67	1.44 [a]
JOG 11-10	0.00	0.00	0.00	0.00 [c]
MBE-SP	0.33	0.33	0.33	0.33 [bc]
NSIC 23	0.67	0.33	0.67	0.56 [b]
NSIC 31	0.00	0.33	0.00	0.11 [bc]
TAIWAN D	0.67	0.67	0.33	0.56 [bc]
Inubi-CA	0.00	0.33	0.33	0.22 [bc]
L-Mean	0.47	0.60	0.60	

*Disease rating: 0-no disease; 1- trace 5% infection; 2-5 -15% infection; 4- 35 to 65% infection; 5 – 67.5 to 100% infection.

Correlation of morphological, physiological, growth, incidence of insect pest and diseases and vine yield characters

The correlation coefficient between the vine yield at vine length (35, 70 and 105 DAP), leaf size (35, 50, and 65 DAP) leaf area index (35, 50 and 65 DAP) of the different physiological, growth, morphological, incidence of pest and diseases to vine yield are shown in Table 6. Results revealed that drought score has negative significant correlation with vine yield. This implies that genotypes lesser drought score produce more vine yield. This collaborates with the findings of Nadler and Heuer (1995) that there is a direct correlation between increasing drought and reduction in yield. Drought causes wilting where cells become flaccid and leaves do not carry assimilation normally (Dar et al., 2003).

Root weight has positive significant correlation with vine yield. This shows that genotypes with heavier roots have higher vine yield. Leaf area was significantly correlated with vine yield. This implies that maintaining large leaves may help in increasing the vine yield of different sweetpotato genotypes. This coincides with the view of Steppler (1981) that among the contributory factor to high yield is the early establishment of large leaf area.

Table 6. Correlation coefficients of morphology, physiological, growth, insect pest incidence, disease incidence to the vine yield.

Characters	Coefficient of correlation	Probability
No. of stomata in abaxial	-0.119ns	0.743
No. of stomata adaxial	-0.098ns	0.787
Drought score	-0.688*	0.028
Recovery rating	+0.471 ns	0.170
Disease incidence	-0.229ns	0.525
Insect pest incidence	+0.229 ns	0.524
Plant vigor	+0.464 ns	0.176
Root weight	+0..883**	0.001
Root length	-0.279 ns	0.436
Leaf area index 65 DAP	+0.289 ns	0.418
Leaf area index 50 DAP	+0.217 ns	0.548
Leaf area index 35 DAP	+0.019 ns	0.958
Leaf area 65 DAP	+0.699*	0.028
Leaf area 50 DAP	+0.106 ns	0.772
Leaf area 35 DAP	+0.166 ns	0.749
Vine Length at 35 DAP	+0.007ns	0.985
Vine Length at 70 DAP	+0.146ns	0.688
Vine Length 105 DAP	-0.057ns	0.876
** = significant at 1% level; ns = not significant; * = significant at 5% level.		

Genotypes JOG 11-10, JK 18-4, JK 7-4, Taiwan D. NSIC 31 and Inubi Ca had drought resistant characteristic such as small leaf area and area index, longest roots, low drought score, high recovery rating and more yield. Plants under moderate stress and severe stress produced smallest leaf area and leaf area index, heaviest roots, longest roots and highest RWC. Production of sweetpotato can be still be feasible in soil with 60 cb soil moisture matric potential. Significant positive correlation between leaf area at 65 DAP and root weight with vine yield in 10 genotypes and negative significant correlation existed in drought score to vine yield.

Genotypes NSIC 23, NSIC 31, Taiwan D. JOG 11-10, JK 7-4, JK 18-4, JK 23-1, BSU # 1, MBE- SP and Inubi-CA can be planted under 60 cb soil moisture matric potential. When soil matric potential is 80 cb genotypes

JOG 11-10, JK 18-1, NSIC 23, Taiwan D. and Inubi-CA can be planted. Characters significantly correlated with vine yield can be used as selection indices for sweetpotato genotypes under water stress condition. Further studies need to be undertaking during dry season for drought resistant genotypes under field condition.

References

Akyeampong, E., 1985. Seed yield, water use, and water use efficiency of cowpea in response to drought stress at different developmental stages. Ph.D. Thesis, Cornell University.

Anselmo, B.A., Ganga, Z.N., Badol, E.O., Heimer, Y.M., Nejidat, A., 1998. Screening sweetpotato for drought tolerance in the Philippine highlands and genetic diversity among selected genotypes. Trop. Agric. 75, 189-196.

Bauder, A., Huss, M., 2009. 20th century climate change inferred from four long-term point observations of seasonal mass balance. Ann. Glaciol. 50(50), 207-214.

Boyer, J.S., 1982. Plant productivity and environment. Sci. 218, 443–448.

Dar, W.D., Gowda, C. L. L., Sharma, H. C., 2003. Role of Modern Science and Technologies in Agriculture for Poverty Alleviation in South Asia. In: South Asia Conference on Technologies for Poverty Reduction, 10-11 October 2003. New Delhi, India.

Farkas, C.S., Randriamampianina, R., Majetcak, J., 2004. Modeling impact of different climate change scenarios on soil water regime of Lollisol. Cereal Res. Commun. 33, 185-188.

Fitter, A. H., Hay, R.K.M., 1981. Physiology of Plants. Ann. Bot. 50(2), 285-288.

Gurgel, R., 2008. Drought Tolerance Mechanisms for Empire Turf. Agronomist and Empire Turf Breeder, Sod Solution, Texas.

Hall, A.E., Schulze, E.D., 1980. Stomatal responses and possible interrelation between stomatal effects on transpiration and CO_2 assimilation. Plant Cell Environ. 3, 467-474.

Hammett, H.L., Constantin, R.J., Hernandez, T.P., 1982. The effect of phosphorous and soil moisture levels on yield and processing quality of centennial sweetpotatoes. J. Amer. Soc. Hort. Sci. 107, 119-122.

Hunt, R., 1978. Plant Growth Analysis Studies Biology. No. 96 Edward Arnold, London. 67p.

ICPRE and UI-CALS, 2002. Potato Response to Drought. In: Ideas for Mitigation of the Effects of a Reduced Water Year. Idaho Center for Potato Research and Education. University of Idaho–College of Agricultural & Life Sciences. Accessed at http://extension.ag.uidaho.edu/droughtpredict/Mitigation.htm.

Laranang, L.B., Tablarin, R.M., 2004. Production of clean planting materials of sweetpotato. Tarlac Coll. Agric. Res. J. 29, 184-189.

Laurie, R.N., du Plooy, C.P., Laurie, S.M., 2009. Effect of moisture stress on growth and performance of orange fleshed sweet potato varieties. Afr. Crop Sci. Conf. Proc. 9, 235–239.

Levitt, J., 1979. Responses of Plants to Environmental Stress.Academic Press, New York. pp.322-445.

Nadler, A., Heuer, B., 1995. Effect of saline irrigation and water deficit on tuber quality. Potato Res. 38, 19-123.

Noggle, G. R., Fritz, G. J., 1983. Introductory Plant Physiology. 2nd Edn. Prentice-Hall, Englewood Cliffs, NS. 627p.

Onyilagha, J.C., 2008. Development of drought tolerant sweet potato for hot-humid Southeast Arkansas and North Mississippi and transfer of technology to farmers. University of Arkansas. Research , Education & Economics Information, USDA.

O'Sullivan, J., Norton, G., van de Fliert, Vasquez, E., Pardales, J., 2005. Sweetpotato DiagNotes: A Diagnostic Key and Information Tool for Sweetpotato Problems. Centre for biological Information Technology, University of Queensland, Australia.

Pan, X.Y., Wang, Y.F., Cao, Q.D., Wang, J., 2002. Relationship between growth redundancy and size inequality in spring wheat populations mulched with clear plastic film. Acta Phytoecol. Sinica 26, 177-184.

Pritchard, S.G., Amthor, J.S., 2005. Crops and Environmental Change: An Introduction to Effects of Global Warming, Increasing Atmospheric CO_2 and O_3 Concentrations and Soil Salinization on Crop Physiology and Yield. The Haworth Press, Binghamton, NY.

Romero, C., Balgorria, G., 1991. The effect of temperature on sweetpotao growth and development. Biological Engineering Department of University of Florida, Gainsvill.

Simane, B., van Keulen, H., Stol, W., Struik, P.C., 1994. Application of crop growth model (SUCROS-87) to assess the effect of moisture stress on yield potential of durum wheat in Ethiopia. Agric. Syst. 44, 337-353.

Steppler, H. A., 1981. A strategy for the International Council for Research in Agroforestry. ICRAF, Nairobi.

Taligan, G. D., Tad-awan, B.A., 2004. Varietal response of potato to drought. BSU Res. J. 44, 107-120.

Valenzuela, H., Fukuda, S., Arakaki, A., 2000. Sweetpotato production guidelines for Hawaii. http://www.extento.hawaii.edu/kbase/reports/sweetpot_prod.htm

van Heerden, P.D.R., Laurie, R., 2008. Effects of prolonged restriction in water supply on photosynthesis, shoot development and storage root yield in sweet potato. Physiol. Plantar. 134, 99-110.

Zaag, D. E., 1992. Potatoes and their Cultivations in the Netherlands. Netherlands Potato Consultative Institute and the Ministry of Agriculture and Fisheries, Foreign Information Service, Wageningen, The Netherlands. 23p.