World Journal of Agricultural Sciences 9 (5): 369-376, 2013
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2013.9.5.1801

Morphological and Chemical Studies on Influence of Water Deficit on Cassava

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Abstract: Because the populations in poor countries are in some cases increasing much faster than their domestic food production and because the dwindling natural resources. So one of the main goals of Agricultural Research is to provide an adequate and secure food source for the ever-expanding populations. Cassava as a major staple food crop in the tropical Africa, Asia and Latin America. With more attention given to cassava by Agricultural Scientists and the International and National Institutions concerned with alleviation of hunger and poverty a future green revolution in more marginal areas might help to prevent further massive starvation in the coming years. So this article presents an overview of cassava response to water stress. Plant grown under three irrigation regimes of field capacity (FC), some morphological parameters were determined. Some physiological and chemical criteria involved in drought tolerance mechanisms such as total soluble sugars, nutrients concentration, starch and protein content were estimated in leaves and storage roots. Results showed that the best result were T25, the ability of plants grown under extreme drought condition may be due to its ability to regulate the osmotic potential, in spite of this reason, but it has a critical threshold for tolerant the drought stress on cassava.

Key words: Cassava · Chemical constituents · Morphological and physiological characters · Water stress

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of the most important staple foods in the human diet in the tropics and is ranked as the third most important of calories in the human diet worldwide, after rice and maize [1]. Cassava is mainly cultivated by small farmers in small plots of poor, infertile acid soils, usually without applications of fertilizers and pesticides [2]. In most areas of cassava production, the crop has to endure a prolonged dry period of several months without rain under these stressful conditions, whereas most of other annual food crops would fail. This ability to produce a good yield under adverse edaphic and atmospheric conditions has earned cassava the reputation of being a "famine reserve crop" [3]. Storage roots are the main agricultural product, although leaves are also eaten in some country, primarily as a protein supplement [4]. Its starchy roots are the harvestable product, consumed either fresh or after processing. In addition to its use as a human food (approximately 60-70% of total production) in Africa, South America and Asia, cassava is also used for animal feed, starch and alcohol production. Although it is grown in a wide range of climates [5]. Cassava can grow in areas with a little than 500 mm annual rainfall and can survive dry periods of 5-6 months. It is therefore widely distributed in the tropical and subtropical ecosystem of Africa with increasing cultivation under unfavorable environments due to its many advantages over other crops. Cassava is known to adapt to conditions of soil water shortage through various mechanisms, such as shedding leaves, closing stomata, osmotic adjustment, increasing root length and decreasing the leaf area. Cassava leaves remain photosynthetically active under prolonged drought, although at a reduced rate and they are capable of partially recovering their photosynthetic

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capacity once released from stress [6]. However, severe soil moisture stress can have adverse effects on crop yield as a result of its effects on plant reproduction processes and root development [7]. Cassava has the capacity to extract water from deep soils (depths of more than 2 m). Although reduction in leaf area leads to water conservation, it is also leads to a reduction in intercepted solar radiation and in total biomass and root yield [8]. When subjected to water stress in the field after establishment of a full canopy, cassava reacts by reducing top growth i.e., leaves and stems [6]. Cassava roots can be stored in the ground but are highly perishable after harvest and hence farmers tend to harvest roots when they are needs [9]. Drought stress tolerance was found in almost all plants but its extent varies from species to species and even within species. Water deficit is global issue to ensure survival of agricultural crops and sustainable food production [10]. Understanding plant responses to drought is of great importance and also a fundamental part for making the crops stress tolerant [11]. The highest dry matter content of cassava tubers is attained when the water stress does not exceed one period in the first 6 months [12]. In moderate water scarcity area of available water, drip irrigation could be used for achieving higher yields of cassava than with zero irrigation [13]. Water for irrigation is becoming both scarce, expensive and necessitates to be utilized in a scientific manner. Among the tuber crops, cassava is the most popular in water deficit areas and its cultivation is gaining importance. In these areas, cassava is generally grown with limited amount of irrigation water. Growth and chemical content of cassava have not been critically examined although response to irrigation was studied. With more attention given to cassava by Agricultural Scientists and the International and National Institutions concerned with alleviation of hunger and poverty a future green revolution in more marginal areas might help to prevent further massive starvation in the coming years. So this article presents an overview on the influence of water deficit on growth and some chemical constituents of cassava.

MATERIALS AND METHODS

Pot experiments were carried out at Faculty of Agriculture, Ain Shams University, Cairo, Egypt during 2011 and 2012. The experiments were laid out in a randomized complete design consisting of three treatments with three replicates. American variety Cassava (*Manihot esculenta* Crantz) stems with five to seven nodes were planted horizontally in pots 50 cm diameter and 70 cm in depth. The crop was maintained at available water for the first month to enhance good crop establishment. Three different water regimes, two which were based on fractions of field capacity (FC), are presented in Table 1. The experimental soil was clay loam and its chemical analyses are shown in Table 2.

Agronomic parameters were determined such as plant height (cm) using a meter ruler by averaging the distance from soil level to the top of plants. Stem diameter, root diameter and root length were (cm) determined by cutting and measuring the diameter using meter ruler. Leaves number was determined by number of leaves by counting. Total leaves area/plant was recorded as cm^2 using a digital leaf area meter (LI-300 portable area meter produced by LI-COR, Lincoln, Nebraska, USA). Sub-samples of the plant parts were taken to determine the fresh weight and dry matter content. Chemical analysis was determined such as total sugars as colorimetrically by using alkaline potassium ferricyanide solution [14]. Starch determination using the method described by Yemm and Willis [15]. The content of macro-nutrients (N, P, K, Ca and Mg) were

Table 1: Experimental treatments description for cropping seasons.

Treatment No.	Treatment label	Description
1	T50 (50%)	Water regime (i.e. 50% FC)
2	T25 (25%)	Water regime (i.e. 25% FC)
3	T0 (control)	Control (i.e. practiced by tap water)

FC - field capacity

Table 2: Chemical analyses of experimental soil.

			Paste soluble ions (meq/l)					Available (ppm)				Total %		
Year	pH	EC dS/m	Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3	Cl^-	N	P	K	N	P	K
2011	8.1	1.25	7.1	3.8	5.8	1.4	4.2	7.0	25.9	90	634	0.25	0.19	0.65
2012	7.9	1.30	6.9	4.0	6.6	1.6	3.8	3.9	23.8	60	475	0.22	0.16	0.48

determined as follows: The samples were dried at 70°C for 72h described by ADAS/MAFF [16]. For mineral analysis, dried leaves were digested in the sulphuric acid and hydrogen peroxide digestion according to the method described by Allen [17].Total nitrogen was determined by Kjeldahl method according to the procedure described in FAO [18]. Phosphorus content was determined using spectrophotometer described by Watanabe and Olsen [19]. Potassium content was determined photometrically using Flame photometer as described by Chapman and Pratt [20]. The metals Ca and Mg were determined spectrometrically using Phillips Unicum Atomic Absorption spectrometer as described by Chapman and Pratt [20].Crude protein was determined according to Kjeldahl method described by A.O.A.C. [21].

Statistical Analysis: The data collected was subjected to combined analysis for the two seasons i.e. 2011 and 2012. Treatments were compared using the statistical analysis system (SAS) software.

RESULTS AND DISCUSSION

Plant Height and Stem Diameter: Results presented in Fig.1 show that water stress reduced plant height and stem diameter of cassava, compared to unstressed control plants, there were significant differences among treatments. There were significant differences for stem growth parameters [22]. And this result is similar to that, water stress reduced plant height in stressed plants, this was attributed to reduction of stem [23].The reduction in plant height was associated with a decline in the cell enlargement and more leaf senescence under water stress conditions [24]. It has been established that drought stress is a very important limiting factor at the initial phase of plant growth and establishment. It affects both elongation and expansion growth Water stress greatly suppresses cell expansion and cell growth due to the low turgid pressure. Osmotic regulation can enable the maintenance of cell turgor for survival or to assist plant growth under severe drought conditions in pearl millet [25].

Number of Leaves and Leaf Area: As shown in Fig. 2. Leaf area was decreased respectively in cassava, the best result was at T25. Inhibition of both cell expansion and the production of cells contributed to losses in leaf area, depending on the developmental stage at which a leaf was stressed. Generally, it was observed that growth resumes after a mild, short-term stress, but growing cells may not expand fully to the size of controls and water stress may reduce the number of cells produced per leaf [26]. In leaves that were no longer engaged in cell division, diminished cell expansion affected leaf area by reducing mature cell size whereas, in younger leaves, inhibition of cell division resulted in fewer cells per leaf [27]. Development of optimal leaf area is important to photosynthesis and dry matter yield. Water stress mostly reduced leaf growth and in turns the leaf areas in many species of plants [28]. Water stress reduced plant height in plants stressed, this was attributed to reduction of leaf expansion [23].To examine the effect of water stress on number of leaves and leaf area, there were significant differences among treatments as shown in Fig. 2. Number of leaves was decreased respectively.

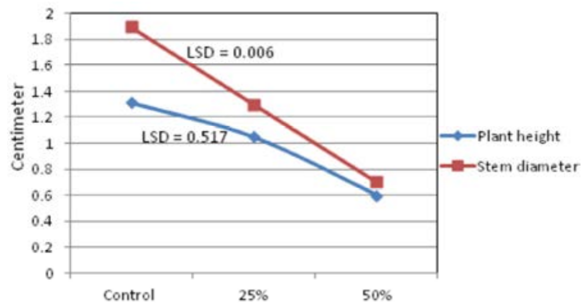

Fig. 1: Effect of water stress on plant height (cm) and stem diameter (cm) of Cassava (Combined analysis of the two seasons 2011and 2012).

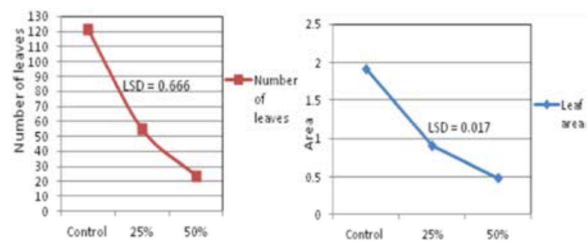

Fig. 2: Effect of water stress on number of leaves and leaf area (cm2) of Cassava (Combined analysis of the two seasons 2011and 2012).

The best result was at T25. The rate of new leaf initiation by apical meristems can limit future growth [29]. The reduction in leaves number may have been a result of reduction and termination of new leaf production and also leaf abscission under water stress conditions [30].

Fresh and Dry Weight of Shoots and Roots: Data in Fig. 3 show that, shoot fresh and dry weight and also root fresh weight was decreased under water stress condition i.e. when plants received 50 % from field capacity, there

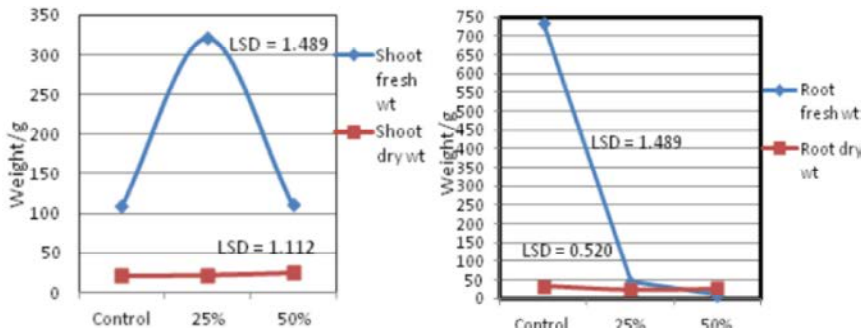

Fig. 3: Effect of water stress on (shoot & root) fresh and dry weight of Cassava (Combined analysis for the two seasons 2011and 2012).

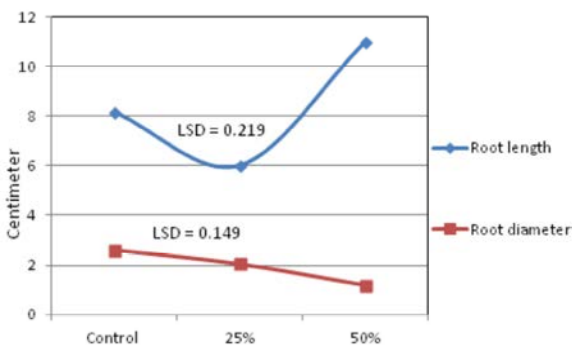

Fig. 4: Effect of water stress root length and diameter (cm) of Cassava (Combined analysis for the two seasons 2011and 2012).

were significant differences among treatments. The reduction in the fresh and dry weight mainly due to the reduction in leaf area which leads to water conservation and also reduction in intercepted solar radiation and in total biomass and root yield [8]. Plant productivity under drought stress is strongly related to the processes of dry matter partitioning and temporal biomass distribution [31]. Plant fresh and dry weights under water limited conditions are desirable characters. A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production [28]. The irreversible leaf senescence caused by water stress may have reduced shoot dry weight [23]. Similar result was found by Odubanjo *et al.* [13]. That, there are significant differences in dry leaves and stems under water stress conditions. During the periods of cropping season, average total shoot and root dry weight increase was high in T50 and similar for T25 and T0. The distribution pattern of dry matter among the different organs of cassava plant was changed markedly during the growth cycle, with shoot having a dominance in the first 3-5 months, while storage roots become major sink for photo assimilates during the rest of the growth cycle [9].The variations in the average total dry matter production and tuber yield (dry matter) were due to the soil nutrients, regime of water application, environmental conditions and cassava cultivar [32,33].The resulting decrease in leaf area is one of the mechanisms of moderating water loss from the canopy and averting excessive drought induced injury to the plant. This however may result in decreases in total dry matter production because of reduction in photo synthetically active leaf area [23].

Length and Diameter of Root: Result in Fig. 4. Show that, root length and diameter were decreased when cassava plants subjected to severe water stress. There were significant differences among the irrigation treatments. In cassava growth, the importance of root systems in acquiring water has long been recognized. A prolific root system can confer the advantage to support accelerated plant growth during the early crop growth stage and extract water from shallow soil layers that is otherwise easily lost by evaporation [34].The development of root system increases the water uptake and maintains requisite osmotic pressure through higher proline levels [35]. Production of root system under drought is important to above ground dry mass and the plant species or varieties of a species show great differences in the production of roots [36]. These results are in conformity with the findings of Odubanjo *et al.* [13].

Nutrients Uptake and Protein Contents: Effect of water stress on nutrient is presented in Fig. 5. Nitrogen content in the leaves was the highest followed by K and Ca, while the lowest content was P and Mg. Similar results were reported by Paula *et al.*[37],who pointed that, total nutrient absorption was highest for N followed by K, Ca,

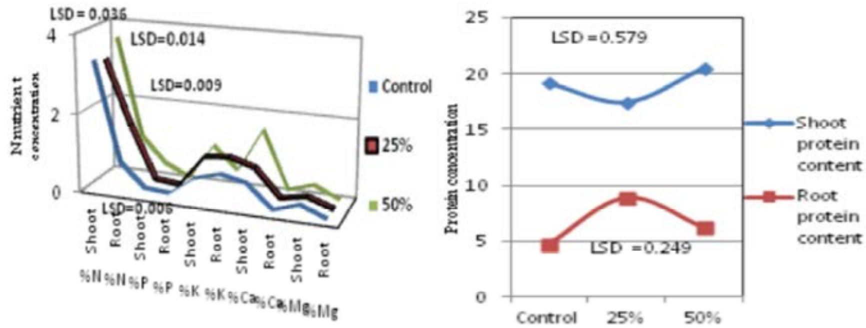

Fig. 5: Effect of water stress on nutrient concentration (%) and protein content (%) of Cassava (Combined analysis for the two seasons 2011and 2012).

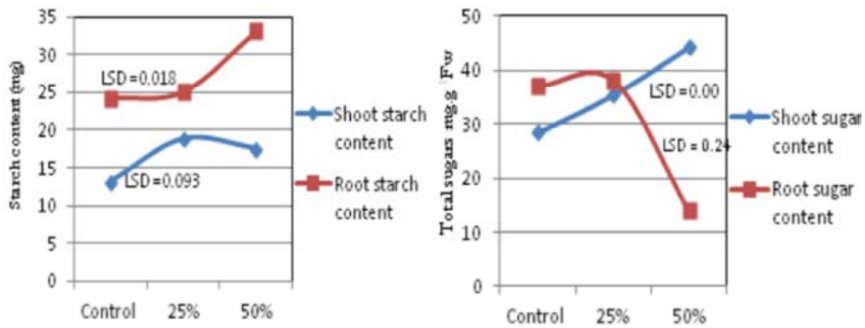

Fig. 6: Effect of water stress on starch content (mg) and total sugars concentration (mg.g-1FW) of Cassava (Combined analysis for the two seasons 2011and 2012).

Mg, P. The roots generally accumulated more K than N, followed by P, Ca, Mg. Similar results were reported by Putthacharoen *et al.* [38]. Generally, higher N levels in the leaves enhance photosynthesis and delay leaf senescence [39], most nutrients are absorbed by plant roots as ions and water is the medium of transport. Under well irrigated conditions when soil water potential is high, the absorption and transport of water and nutrient are higher. Drought stress decreases nutrient transport by diffusion and mass flow to the root surfaces and nutrient absorption by roots, which is influenced by water potential. Under water stress, roots are unable to take up nutrients from the soil because of lack of activity of fine roots, water movement and ionic diffusion of nutrients. Drought influences nutrient uptake not only via effects of nutrient availability at the rhizoplane but also by altering nutrient capability of mycorrhizal or nonmycorrhizal roots [40]. Fig. 5 shows that, protein content was decreased in shoot when plants subjected under T50 and increased in root under T25. Leaves of cassava are a considerable source of protein. Protein contents under drought were higher in the sensitive genotype as compared to the moderately tolerant genotype [41]. Drought reduces nutrient uptake by roots and their transport from roots to shoots because of restricted transpiration rates, impaired active transport and membrane permeability. Plants may increase its drought tolerance by decreasing osmotic potential by accumulation of solutes, which allows cell enlargement, plant growth, keeps open stomata and CO_2 assimilation under water stress.

Starch Content and Total Sugars: Effect of water stress on starch is presented in Fig. 6. Starch content was increased in root when plants subjected under T50, while was increased in shoots under T25. Total sugars were high with T50 in shoot, while it was similar with T0 and T25 in root and low with T50. The plants, after surviving such stress conditions, will recover quickly by forming new leaves; the energy for this process is obtained by utilizing reserve starch. The net effect is a reduction in starch content and starch quality. In contrast, immature plants cultivated under water stress conditions rarely grow throughout the dry period and do not seem to elicit a regulatory mechanism; starch is therefore not effectively synthesized. With resumption of rainfall, plants start growing and starch is synthesized, yet the influence of initial water stress, on starch quality, is still sustained [42]. Root starch and total sugars were unaffected by irrigation while reduced sugars was significantly changed by irrigation Plant has osmotic adjustment and sustained yield and biomass under water stress conditions [43]. Having high level maintenance of water in all treatments (water deficit and excess water), prevents accumulation of osmotic adjustments, like proline and total soluble sugars. The accumulation of osmolyte compounds in the cells, as a result of water stress is often associated with a possible mechanism to tolerate the harmful effect of water shortage [44].

Cassava starch is used directly as starch and indirectly as depolymerized products in various industries due to its high purity, very low cost and unique characteristics such as clear viscous starch paste [45].Variation in starch quality seems to start in the roots. Identification of the factors responsible for such variation has been attempted. The factors fall into two broad categories, those derived from genetic variation and those influenced by environmental conditions [46]. Water availability, both early or late in the plant development, is critical for starch yield and quality. Mature plants seem to be more capable of adapting to water stress through regulatory mechanisms such as reduction of leaf canopy, utilization of deep soil water and being able to withstand prolonged stress conditions while maintaining photosynthetic activity. Both starch yield and quality are dependent on planting date and time of harvest [47].

CONCLUSION

Drought stress is considered to be major environmental factors limiting crop growth and yield. Drought stress induces many morphological and biochemical changes and responses that influence various cellular and whole plant processes that affect growth and chemical contents. Crop performance in terms of growth, development and biomass accumulation depends on the crop's ability to withstand, acclimate, or recover from the stress. The results of this study confirmed earlier findings and added new clear field evidence of cassava response to different water regimes through supplemental irrigation. From this study, it can be recommended that in areas where water is very scarce, cassava can be tolerance drought stress with T25. So we can say that for cassava, it has a critical threshold for tolerant the drought stress on cassava.

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