

Assessment of Anchote Breeding and Its Physiological Adaptive Mechanisms for Moisture Stress

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Abstract
Anchote (Coccinia abyssinica), is a perennial climbing, monoecious root crop, endemic and indigenous to Ethiopia. It is the richest in protein, iron, calcium and phosphate contents with minimum anti-nutritional content as compared to other root and tuber crops. Despite its importance the production and productivity is hampered by biotic and abiotic factors. Among the abiotic factors drought stress is the most serious threat to world food security. Therefore, understanding the extent of drought stress and assessing the mechanisms of drought tolerance in plants is very crucial to devise different coping mechanisms with the stresses. The information generated in this review may serve as a guideline in future Anhote improvement programs in terms of moisture stress tolerance.
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1. Introduction

Anchote (Coccinia abyssinica (Lam.) Cogn.) is a perennial trailing vine, monoecious root crop that belongs to family Cucurbitaceae. The genus Coccinia comprises 27 species, all of which are confined to sub-Saharan Africa where it is diversified into various habitat types (Holstein and Renner 2011). A total of eight species of Coccinia are found in Ethiopia (Jeffrey, 1995). Among these species, C. abyssinica is the only species cultivated for its edible tuberous roots and the young shoots used as leaf vegetables (Fekadu D 2011). It is mostly cultivated in backyards and grows in the south, south west and western parts of the country (EIAR 2008).

Anchote has a good nutrient composition with a good supplement of vitamins and minerals compared to other tuber crops, and regarded as a leading protein root crop (Fufa and Urga, 1997). Apart from food, the crop is also used in traditional medicine. It contains high quantities of nutrients like crude fiber, protein, calcium, iron, zinc and magnesium, which is rare in other tuber crops. According to local farmers, it helps in fast mending of broken bones and displaced joints. Due to its good vitamin A content, consumption of anchote may also help to reduce the problem of vitamin A deficiency. Traditionally, it is also believed that anchote makes lactating mothers healthier and stronger. Flour made from the tuber may be used as a supplementary food for infants and young children. Furthermore, juice prepared from anchote tubers has saponin as an active substance and is used to treat gonorrhea, tuberculosis, and tumors.

Anchote grows in areas with altitudes ranging from 1300 to 2400 m.a.s.l. (Edwards *et al.,* 1995). It prefers soil pH of 4.5 to 7.5, mean minimum and maximum temperature of 12 ^{o}C and 28 ^{o}C and rain fall ranging from 800 to 1200 mm/year (Getahun, 2015; Bekele 2017). The storage root yield of anchote on research field range 42-76 ton per hectare, as compared to other root and tuber crops yield its high (Daba *et al*., 2012).

The food potential of root and tuber crops has not yet been fully exploited and utilized despite their significant contributions towards food security, income generation, provision of food energy and resource base conservation (EIAR, 2008). The low agricultural productivity, recurrent drought and socio-political factors have greatly contributed to critical food shortages in Ethiopia coupled with over-dependency on few cereal crops; thus, integration of root and tuber crops into the food system of the people should be given a serious attention. Despite its high yield in small area of land, multipurpose advantage and its importance as a food security crop in Ethiopia, the production and consumption of Anchote is almost negligible due to the lower attention given to the research and development. Therefore, this review study is initiated to assess the importance of production, reproduction and propagation method, genetic diversity, plant response to water stress, mechanism of adaptation to water stress and method of screening for drought tolerance. The information generated could be exploited in devising future research and production strategies on improving yield, biotic stress (quality, disease and insect-pest) tolerant and abiotic stress (drought, acid, etc) tolerant Anchote.

2. Importance's of Anchote production

Root and tuber crops are main stays for millions of people and occupy an important position in world agriculture. Anchote is among the major root and tuber crops grown in western and southern parts of Ethiopia (Daba *et al*., 2012). One of the desirable qualities of anchote as a tuber crop is its good keeping quality. The tubers can be stored in an underground pit and retrieved when needed, providing food security in times of other crop failures. Although information on nutritional and anti–nutritional contents of anchote's leaf and seed is limited, the root has been better studied and reported as possessing a higher nutritional content than other common and widespread root and tuber crops (Habtamu and Kelbessa, 1997). Anchote has a good nutrient composition with a good supplement of vitamins and minerals compared to other tuber crops, and regarded as a leading protein root crop (Table 1). Its protein content is also by far greater than other root crops, although, root crops are known for their low protein content. According to Fekadu (2011) the raw Anchote tuber contains organic (carbohydrate, crude protein, crude fiber) and inorganic substances (calcium, magnesium, iron) as well as low levels of antinutrients (Oxalate, tannin, and cyanide) except phytate, when compared to other tuberous crop plants. Root and tuber crops are one of the important sources of minerals that are linked to prevent deficiency diseases such as Anemia and Rickets, and daily consumption of these foods is being encouraged (Leterme, 2002). Anchote is plant endemic in Ethiopia with a high calcium content grown for its edible tuberous roots. Calcium is the major component of bone and assists in tooth development. Calcium concentrations are also necessary for blood coagulation and for the integrity of intracellular cement substances (Okaka J.C. and Okaka A., 2001). Anchote has been recommended to treat individuals suffering from bone fracturing, displaced joints and other diseases such as gonorrhea, tuberculosis, and cancer (Dawit and Estifanos, 1991; Dandena, 2010). This may be because of its high calcium and protein contents that repairs damaged bones; however, peeling of anchote during cooking reduces its nutritional contents (Habtamu and Kelbessa, 1997). Anchote was a fibrous materiel while the fiber is most important to reduce colon cancer, diabetes, heart diseases and the level of low - density lipoprotein cholesterol in blood and other numerous health benefits. It also ensures smooth bowel movements and thus helps in easy flushing out of waste products from the body, increase satiety and hence impacts some degree of weight management. High fiber content increases the utility of Anchote flour in various food products. However, emphasis has been placed on the importance of keeping fiber intake low in the nutrition of infants and weaning children because high fiber levels in weaning diet can lead to irritation of the gut mucosa (Bello *et al*., 2008).

Table 2.1. Major nutrient composition and mineral content of *Anchote* compare with other edible tuber crops.

Type of Tuber	Moisture	Protien	Carbo hdrate	Crud fat	Total ash	C. fiber	Energy (Kcal)	Ca	Fe	K	Mg	Source
Anchote	74.93	3.25	16.86	0.19	2.19	2.58	82.1	119.5	5.49	34.6	79.7	Habtamu *et al*., 2015
Sweet potato	67.40	1.30	28.20	2.00	1.10	1.10	136.0	52.0	3.40	34.0	25.0	Jemziya & mah edran, 2015
Potato	74.70	1.60	22.60	0.10	0.60	0.40	97.0	10.0	6.70	40.0	21.0	Holloway,1988
Oromo potato	81.20	1.50	16.00	0.20	1.10	0.70	71.0	29.0	9.30	90.0		Habtamu, 2011
Enset	48.70	0.60	49.00	0.30	0.90	1.20	200.0	82.0	3.70	36.0		Mohamed *et al*., 2013
Cassava	82.12	0.53	31.00	0.17	0.84	1.48		20.0	0.23	46.0	30.0	Monaggnac *et al*., 2009

Kcal= kilo calorie, Ca = calcium, Fe = iron, K = potassium and Mg = magnesium

3. Anchote Reproduction and Propagation Methods

Anchote (*Coccinia abyssinica*), is a perennial climbing, monoecious root crop and requires support to climb on it by means of its simple tendrils (Edwards *et al*., 1995). It undergoes an annual cycle of death and regeneration of herbaceous shoots, the condition known as hemicryptophytic life form (Schaefer and Renner, 2011).The male and female flowers occur on separate nodes of the same plant. The two flowers bloom at different time (a dichogamy situation called protandry) (Edwards *et al*., 1995). This nature, obviously, invites outcrosses and prevents inbreeding. As protandrous species tend to be pollinated by bees or flies (Sargent and Otto, 2004), anchote is mainly pollinated by bees (Edwards *et al*., 1995).The reproduction mechanism involve both sexual and asexual, since anchote can grow from seed and vegetative parts (root). The latter method involves either planting a root as a whole or by splicing it into pieces, as far as each piece has rootlets and an external covering. Asexual propagation method is usually done to establish "mother" plant, called "Gubo" in Oromigna language,or "ajji indee" in Kaffigna language which serves as a seed source for further plantings (Fig. 1). Stem cutting may be, sometimes employed for anchote propagation. However, for commercial production, seed is preferred over other methods (Abera Hora *et al*., 1995). Seed for the next year sowing are harvested from plants of good quality including size, color or other traits and stored, usually after mixing with ash, in pots or any other containers made of clay materials. Since anchote root has a dormancy period of many years, farmers keep it in the soil as a method of preserving selected anchote. For consumption, the roots are harvested by digging them up from the soil (Abera Hora *et al*., 1995).

A single anchote plant provides many fruits, from which hundreds of seeds are extracted. In the next growing season, the seeds will be sown and enough anchote can be produced for home consumption (Abera

Hora *et al.*, 1995). While seeds are extracted from fully mature red-ripe fruits, which are harvested before they start rooting. Such fruits are macerated or sliced to separate the seeds from the fleshy juicy part (Ambecha, 2006). The seeds are then mixed with an equal quantity of wood ash and dried in under shade conditions. The moisture content of the seeds for storage is based on the desired level. During this storage period the seeds are usually kept in either clay or wooden pots or wrapped in a sheet of cloth (Ambecha, 2006).

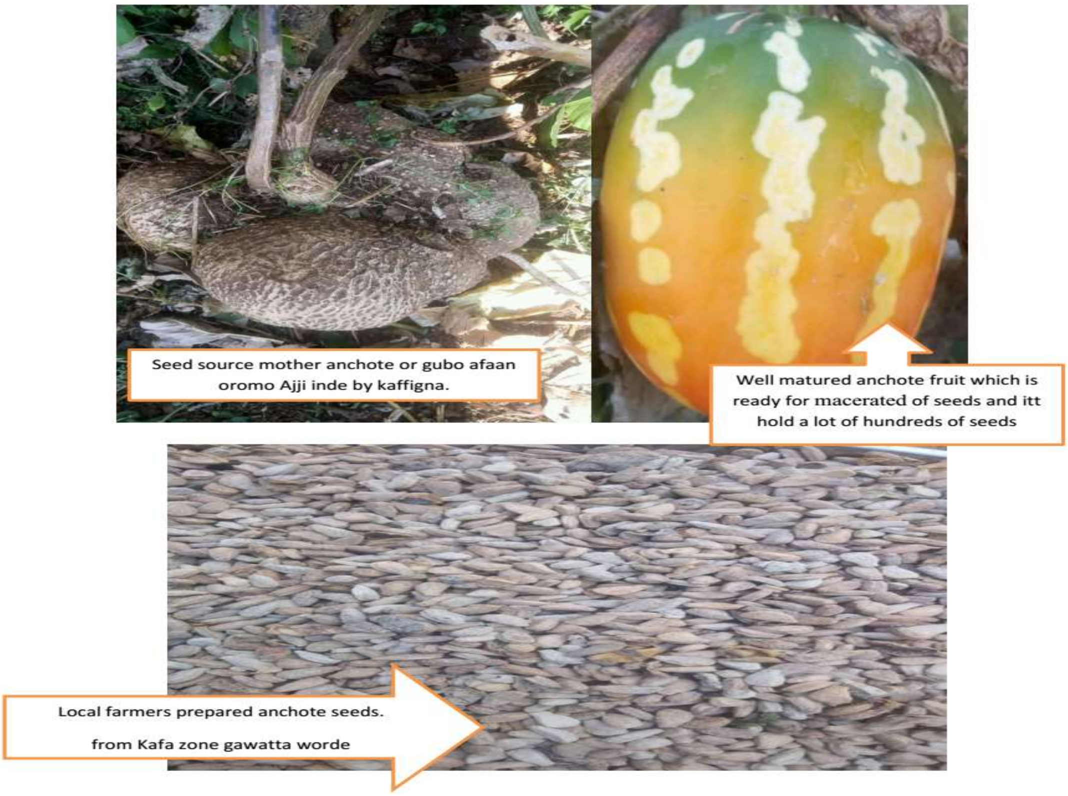

Figure 1. Propagation material for anchote.
Source: Keffa zone, Gawata woreda, Addis brehan kebele farmers garden as cited by Ambecha, 2006.

4. Genetic Diversity of Anchote

Genetic diversity is referred to as the sum total of genetic variations found in a species or population and it is source for ecological biodiversity. Genetic variability, which is due to the genetic differences among individuals within a population, is the core of plant breeding because proper management of diversity can produce permanent gain in the performance of plant and can buffer against seasonal fluctuations (Sharma, 1998). Measuring genetic diversity is significant to examine variations present among the organisms on the basis of genetic markers at phenotypic, biochemical and genotypic level. It is a prerequisite for efficient breeding plans, collection expeditions or germplasm exchange in order to acquire specific characteristic (Abebe and Bjornstrand, 1996). Genetic diversity can be measured by counting the number of different genes in a gene pool, but genetic variation can only be expected to occur and cannot be measured. Genetic variability thus, can be considered as the building blocks of genetic diversity. Genetic diversity is the base for survival of plants in nature and for crop improvement. Diversity in plant genetic resources provides opportunity for plant breeders to develop new and improved cultivars with desirable characteristics, which include both farmer-preferred traits (high yield potential, large seed or tuber, etc.) and breeder-preferred traits (pest and disease resistance high quality, drought tolerant and photosensitivity, etc.).

Higher level of genetic variability with molecular markers (ISSR) was observed among 12 anchote accessions collected from Ethiopia (Abreham *et al.,* 2014) and also by a multivariate analysis of phenotypic characters the presence of wide range of variation were observed among 49 accessions of Anchote (Tilahun *et al.*, 2014). Several phenotypic and few molecular studies revealed that the populations of *Coccinia abyssinica (Lam.) Cogn.* from the southwestern part of Ethiopia have high genetic variability (Fekadu D., 2011; Fekadu H., 2011; Mengesha *et al*. 2012; Abreham *et al.,* 2014; Tilahun *et al.*, 2014). Since Ethiopia is the only centers of origin and diversifications of Anchote (*Coccinia abyssinica (Lam.) Cogn.*)*,* there is a high genetic diversity, which is mainly attributed to its diverse ecological features such as climatic and edaphically conditions (suitable altitude, ample rainfall, optimum temperature, fertile soils) (Jeffrey, 1995; EIAR, 2008).

5. Plant Responses to Water Stress

Water stress in plants reduces the rate of photosynthesis by decreasing both leaf area and photosynthetic rate per unit leaf area (McCree, 1986). The decrease in leaf growth or increasing senescence of leaves under drought conditions may also inhibit photosynthesis in existing leaves (Boyer, 1976). Decreasing water content is accompanied by loss of turgor and wilting, cessation of cell enlargement, closure of stomata, alteration of photosynthesis and interference with many other basic metabolic processes (Kramer and Boyer, 1995). Continued photosynthetic light reactions during drought stress under limited intercellular CO2 concentration results in the accumulation of reduced photosynthetic electron transport components, which can potentially reduce molecular oxygen, resulting in the production of reactive oxygen species (ROS). ROS can cause severe damage to the photosynthetic apparatus (Lawlor and Cornic, 2002).

Major phytohormones, such as abscisic acid (ABA), cytokinin (CK), gibberellic acid (GA), auxin, and ethylene, regulate diverse processes which enable plant adaptation to drought stress (Wilkinson *et al.*, 2012). Upon exposure of plants to drought stress, ABA is the major hormone synthesized in roots and translocated to leaves to initiate adaptation of plants to drought stress through stomatal closure and reduced plant growth (Wilkinson and Davies, 2010). However, modulating the ABA-induced drought adaptation of plants for better yield remains a greater challenge because of the potential inadvertent reduction in carbon gain upon stomatal closure and ABA-induced senescence, especially if the drought occurs at the reproductive stage (JiX *et al.*, 2011). Under drought stress, CKs are known to delay premature leaf senescence and death, adaptive traits very useful for increasing grain yield. An increase in the endogenous levels of CK through expression of *isopentenyltransferase* (*IPT*), a CK biosynthetic pathway gene, leads to stress adaptation by delaying droughtinduced senescence and an increase in yield (Peleg *et al*., 2011; Peleg and Blumwald, 2011). Generally, auxin has been shown to negatively regulate drought adaptation in plants. Decrease in indole-3-acetic acid (IAA) content was shown to be associated with up-regulation of genes encoding late embryogenesis abundant (LEA) proteins, leading to drought adaptation in plants (Xie *et al.*, 2003; Zhang *et al.*, 2009). GA is suggested to positively regulate plant adaptation to drought stress. A rapid decline in levels of endogenous GA was observed in plants subjected to drought stress, resulting in growth inhibition (Wang C. *et al.*, 2008). Ethylene is a negative regulator of drought stress response by promoting leaf senescence and inhibiting root growth and development, shoot/leaf expansion, and photosynthesis (Munné-Bosch and Alegre, 2004; Rajala and Peltonen-S., 2001). Therefore, the net outcome of the drought stress response is regulated by a balance between hormones that promote and those that inhibit the trait, rather than individual hormones (Basu *et al*., 2016).

The immediate response of plants on being exposed to drought stress is stomatal closure. However, stomatal closure not only diminishes water loss through transpiration but also reduces CO2 and nutrient uptake, and hence alters metabolic pathways such as photosynthesis (Xiong and Zhu, 2002). Plants growing in dry areas have developed xeromorphic traits to reduce transpiration under drought stress. Reduction in transpiration under drought stress conditions can also be achieved through leaf shedding (i.e. deciduous species in drought) as well as decrease in leaf number, leaf size, and branching. Another adaptation to counter drought stress is sclerophylly, where plants form hard leaves that will not suffer permanent damage due to wilting and can be restored to full functionality when normal conditions resume (Micco and Aronne, 2002). Recent research has shown that decreased stomatal conductance in response to drought stress is related not only to reduced expression of aquaporin genes but also to anatomical traits leading to reduction of chloroplast surface area exposed to intercellular space per unit leaf area (Miyazawa *et al*., 2008; Tosens *et al*., 2012).

The growth of the primary root is not affected by drought stress but, the growth of lateral roots is signifcantly reduced, mainly by suppression of the activation of the lateral root meristems (Deak and Malamy, 2005). The expression of enzymes related to root morphology (e.g. xyloglucan endotransglucosylase) is induced upon mild drought stress, while other structural proteins are down-regulated, which is strongly correlated with root growth and hence an augmentation in the surface area for water uptake. The alterations in the expression of these proteins correlate positively with lateral development that in turn also affects photosynthesis (Sengupta and Reddy, 2011). Presences of specialized tissues like rhizodermis, with a thickened outer cell wall or suberized exodermis, or reduction in the number of cortical layers are considered an adaptive advantage for drought stress survival. Hydrotropism is another adaptive measure taken by plants to counter stress, where studies have shown that degradation of amyloplasts in the columella cells of plant roots on exposure to drought stress increases hydrotropism (Jaffe *et al.*, 1985; Takahashi *et al.,* 2003). Hormonal cross-talk mediated by auxin, CK, GA, and ABA has been implicated as a potential chemical signal in response to water stress to modulate root system architecture (Blilou *et al.,* 2005).

Cell enlargement and growth in plants is highly dependent on water availability and helps in maintaining the turgor. Turgor measurement in growing regions of plants, especially the leaves and stems, shows little or no reduction, though cell enlargement is inhibited during drought stress and is believed to be due to osmotic adjustment (Meyer and Boyer, 1972; Serraj and Sinclair, 2002). Under conditions of drought stress, osmotic adjustment has been implicated in maintaining stomatal conductance, photosynthesis, leaf water volume, and growth (Oosterhuis and Wullschleger, 1987). At times of drought stress, in addition to the reduction in water content, there are also other associated changes, such as increases in salt concentration and mechanical impedance (Sauter *et al.*, 2001).

6. Mechanisms of adaptation to drought stress

Moisture stress occurs when the water in a plant's cells is reduced and less than normal levels. This can occur because of a lack of water in the plant's root zone, higher rates of transpiration than the rate of moisture uptake by the roots, for example, because of an inability to absorb water due to a high salt content in the soil water or loss of roots due to transplantation. Moisture stress is more strongly related to water potential than it is to water content. There are four different mechanisms which in survival of plants under moisture deficit conditions such as drought escape, drought avoidance, drought tolerance and drought resistance. Drought resistance (DR) is a broader term applied to plant species with adaptive features that enable them to escape, avoid, or tolerate drought stress (Levitt, 1980). Drought escape is the ability of a plant species to complete its life cycle before the onset of drought. Thereby, plants do not experience drought stress, as they are able to modulate their vegetative and reproductive growth according to water availability, essentially through two different mechanisms: rapid phenological development and developmental plasticity (Jones *et al.,* 1981). Rapid phenological development involves rapid plant growth, producing a minimal number of seeds before the soil water depletes, and these plants are considered not to have any special morphological, physiological, or biochemical adaptations. Plants with mechanisms of developmental plasticity show little growth during the dry season, with very few flowers and seeds, but in wet seasons they grow indeterminately, producing a large amount of seed. Drought avoidance is the ability of plants to maintain (relatively) higher tissue water content despite reduced water content in the soil (Levitt, 1980). This is achieved through a variety of adaptive traits involving the minimization of water loss (water savers) and optimization of water uptake (water spenders). Water spenders achieve higher tissue water status by maintaining the water uptake through increased rooting, hydraulic conductance, etc. under drought stress. In contrast, water savers use water effectively through reduced loss of water by reducing transpiration, transpiration area, radiation absorption, etc. under drought stress. Drought tolerance (DT) is the ability of plants to endure low tissue water content through adaptive traits. These adaptive traits involve maintenance of cell turgor through osmotic adjustment and cellular elasticity, and increasing protoplasmic resistance (Morgan, 1984). The interaction and adaptation of plants to environmental signals and stresses is a complex network model (Shwani *et al.,* 2010). Figure1 highlights the probable physiological, biochemical and molecular responses to drought-stress in higher plants. Plants can withhold the drought stress by dehydration tolerance, dehydration avoidance or drought escape (Ludlow, 1989).

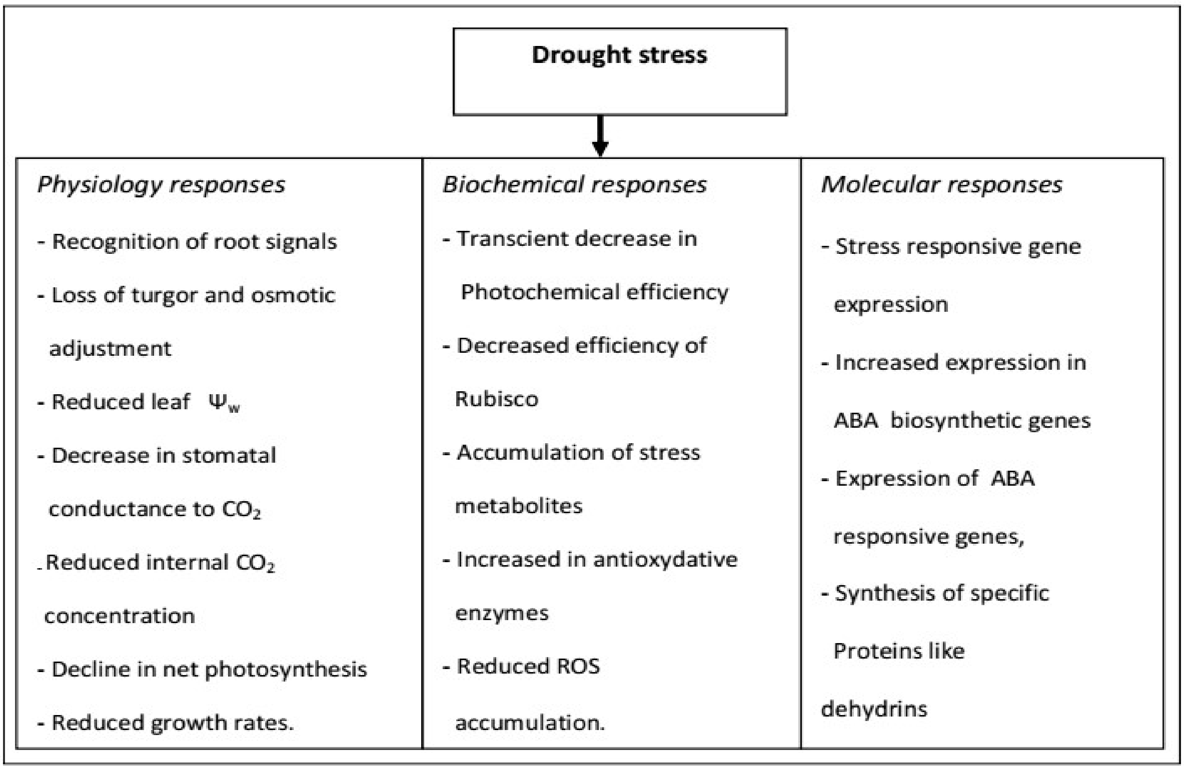

Figure1. Physiological, biochemical and molecular responses to drought stress in plants (Reddy *et al.*, 2004).

Plants that are always green present sometimes thick leaves with solid cuticle, deep roots, highly sclerophyllous and reduced size leaves, and effective water use and control of evapotranspiration (Ain-Lhout *et al.*, 2001; Lebreton *et al.*, 1995; Sanguineti *et al.*, 1999; Sorrells *et al.*, 2000; Taiz and Zeiger, 2006). These strategies are usually assisted by others such as accumulation of compatible solutes and increased expression and production of antioxidants. Accumulation of compatible solutes is one of biochemical processes that help plants to survive under drought condition (McCue and Hanson, 1990). Compatible solutes play an adaptive role by osmotic adjustment and protection of cellular compounds (Ain-Lhout *et al.*, 2001; Hare *et al.*, 1998). The compatible solutes are mainly nitrogen containing molecules such as amino acids and polyamines, and hydroxyl compounds. Types of these compatible solutes and the level of their accumulation vary with plant species (McCue and Hanson, 1990). These molecules work together with antioxidants which intervene to eliminate ROS and repair damages of ROS.

Mechanisms of dehydration avoidance such as stomatal closure and a decrease of leaf area reduce the assimilation of light and atmospheric CO2 necessary for photosynthesis (Cornic, 2000; Lawlor and Tezara, 2009). Dehydration tolerance with the accumulation of compatible solutes, the synthesis of antioxidants and the process of ROS scavenging requires too much plant energy. Consequently, these mechanisms reduce the ability of plants to synthesize organic products for stock organs (Mitra, 2001). Thus, the development of a drought tolerant variety such as sweet potato needs to balance all drought tolerance mechanisms without sacrificing the crop productivity (Mitra, 2001; Passioura, 1996; Richards, 1996).

According to Getahun (1973), anchote is a drought tolerant dry land crop with wider ecological adaptation. Anchote can tolerate stress environmental condition by different physiological mechanisms such as Leaf rolling and by shading their leaves when moisture stress comes (personal observation).

7. Screening for drought tolerance

Study of drought tolerance in plants can be carried out under field or controlled environmental conditions (Acquaah, 2007). The field condition consists of conducting trials under natural conditions. These trials are carried out in the real environments of a plant but it has some limitations of fluctuation of water availability caused by unexpected rainfall. Moreover, environmental factors such as temperature, air humidity and light are variable. Therefore, the screening for drought tolerance is complicated by difficulties of field management (Lafitte *et al.*, 2004). The rainout shelter and *in vitro* techniques were proposed to overcome the limitations of selection for drought tolerance under field condition (Acquaah, 2007). The rainout shelter is a mobile infrastructure that protects plants under experiment from rain. This method controls the uniformity of water supply to plants (Blum, 2002). The *in vitro* approach consists of growing cells or tissues of plant or plantlets on a defined drought stressing culture media under an aseptic and controlled environment (Ahloowalia *et al.,* 2004; Wang *et al.*, 1999).The *in vitro* technique provides precise results but the working environment differs from the natural environment of plant. Therefore, the combination of *in vitro* screening with selection under the natural condition or under the rainout shelter could improve the quality of results (Rukundo *et al.,* 2015). Drought stress tolerance is a complex quantitatively inherited and controlled trait. These stresses affect the plant in different ways and induce different genetic responses. Therefore, very careful strategies and powerful methods are required to assess the level of genetic resistance and/or tolerance. Drought tolerance can be identified by quantifying phenological, morphological, and physiological and biochemical characteristics and using molecular tools (Blum, 2002). Phenological and morphological characteristics are mostly used in breeding for drought tolerance. In these approaches data collection consists of measurement of plant growth (size of roots, stem and leaf area, gain of fresh and dry weights and yield loss), growth stage (days to flowering and maturity), senescence and leaf rolling (Cheema and Sadaqat, 2004; Spitters and Schaapendonk, 1990). The water content and water potential of plant are indicators used to identify drought tolerant varieties. A variety that maintains its internal water status under a drought stress is considered as drought tolerant. Drought tolerance is also determined by quantifying plant biochemical products such as compatible solutes, chlorophyll, antioxidants and other proteins produced by plant as responses to drought stress (Kasukabe *et al*., 2006; Reddy *et al*., 2004; Wang *et al*., 1999). Diffusion porometry for leaf water conductance, root penetration, distribution and density in the field and infrared aerial photography for dehydration and leaf temperature are used commonly in studies for drought tolerance (Mitra, 2001).

8. Conclussion

Roots and tubers have so far been regarded as inferior and neglected food crops even in areas where they are staples. For several decades, studies have examined the problems and potentials of root/tuber crops production, but limited progress has been made in improving the productivity of most of these crops under drought conditions. There are numerous challenges to the development of tuber and root crops, but an intensification of research (e.g., germplasm conservation, improved cultivation methods) is a critical step toward that goal. Among the root/tuber crops, Anchote has probably the greatest potential for development and genetic improvement in part due to its high nutritional value, its ability to be stored for a long period of time and its long dormancy period. Despite these importances, the production and productivity is constrained by different biotic and abiotic factors. The biotic factors drought stress is one of the most serious threats to world food security. There are various negative effects on plant growth and total yield occurs under drought conditions, therefore, plants have different responses to adapt and survive with drought conditions such as morphological, biochemical, physiological responses, and a molecular mechanism. Plants acclimatize with drought stress through use various strategies which include drought escape, drought avoidance and drought tolerance.

There exists a large diversity in drought adaptation within a crop species, as some genotypes are able to cope with drought better than others. Genotypes that differ in drought adaptive mechanisms serve as an important resource to study the variation in drought adaption in crop plants. This natural variation needs to be exploited to simultaneously improve drought resistant and yields of cultivated varieties through better understanding of the underlying mechanisms and to aid in selection for these traits.

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