Plagiarism Checker X Originality Report

Similarity Found: 58%

Effect of Drought stress on Medicinal plants and its tolerance mechanism ABSTRACT Drought stress is especially important in countries where crop agriculture is essentially rain-fed. Drought stress causes an increase in solute concentration in the environment, leading to an osmotic flow of water out of plant cells. This in turn causes the solute concentration inside plant cells to increase, thus lowering water potential and disrupting membranes along with essential processes like photosynthesis.

These drought-stressed plants consequently exhibit poor growth and yield. In worst case scenarios, the plants completely die. Certain plants have devised mechanisms to survive under low water conditions. These mechanisms have been classified as tolerance, avoidance or escape. Medicinal plants have been an integral part of our daily life for thousands of years. Drought is the most important abiotic factor limiting growth, adversely affect growth and crop production. Stress resulting in the non-normal physiological processes that influence one or a combination of biological and environmental factors.

Production is limited by environmental stresses, according to different solar's estimates, only 10 percent of the world's arable land is free from Stress, in general, a major factor in the difference between yield and potential performance, environmental stresses. Drought stress is the most common environmental stresses that almost 25 percent of agricultural lands for agricultural farm products in the world are limited. INTRODUCTION Medicinal plants in any country form a very heterogeneous group in growth habit, distribution, reproduction, phenology and their ecological requirements. Many of them grow in open starting from wetlands to dry, arid conditions.

They also extend from sea level to higher altitudes. The medicinal value of such plants

also might vary; some important ones are mountainous forms, others bordering the desert or semi-desert areas. The quality and quantity of products they produce also vary depending on the habitat. Interest in the exploitation of medicinal plants as pharmaceuticals, herbal remedies, flavourings, perfumes and cosmetics, and other natural products has greatly increased in the recent years (Anon 1994; Ayensu 1996; Salleh et al. 1997; Kumar et al. 2000).

In India alone, less than 10 % of the medicinal plants traded in the country are cultivated, about 90% are collected from the wild, very often in a destructive and unsustainable manner (Natesh 2000). The medicinal plants have been used by humans from the pre-historical times. Some examples of medicinal plant from the Asia-Pacific region are of species such as Rauvolfia, Hyoscyamus, Cassia, Atropa, Podophyllum, Psoralea, Catharanthus, and Papaver. Though much information exists on the species diversity in medicinal plants in the Asia-Pacific region, relatively very little is known about the distribution, abundance, ecology and genetic diversity of the great majority of medicinal and aromatic plants, although some efforts have started in recent years (Chadha and Gupta 1995; Chandel et al. 1996; Kumar et al. 2000; Paisooksantivatana et al. 2001), including the use of molecular markers (Sharma et al 2000; Natesh 2000).

Out of the 350 000 plant species identified so far, about 35 000 (some estimate up to 70 000) are used worldwide for medicinal purposes and less than about 0.5% of these have been chemically investigated. The global market for the medicinal plants and herbal medicine is estimated to be worth US$800 billion a year (Rajasekharan and Ganeshan 2002). More than 8000 plant species are known for their medicinal properties in the Asia-Pacific and about 10% of them are used regularly, mostly collected from wild.

For example, it has been estimated that not less than 7500 species of medicinal plants exist in the Indonesian archipelago, of which only about 187 species are used as basic materials in traditional medicines industries (Hamid 1990). In China, over 4000 species of medicinal plants have been reported (Ayensu 1996). In India, about 2500 species are used for medicinal purposes, and about 90% of the medicinal plants provide raw materials for the herbal pharmaceuticals, which are collected from the wild habitats (Rajasekharan and Ganeshan 2002).

About 2000 medicinal plants species are reported from Malaysia (Latif 1997), while in an another account 1200 species have been reported to have potential pharmaceutical value, some of which are being used as herbal medicines (Kadir 1997). For the Indian Himalayan Region, a total of 1748 species of medicinal plants – 1020 herbs, 338 shrubs, 339 trees, apart from 51 pteridophytes – have been listed (Samant et al. 1998). These include several of the endangered medicinal plant species, using current IUCN, Red Data

criteria under the Biodiversity Conservation Prioritization Project (BCPP), by Conservation Assessment and Management Plan (CAMP) workshop organized by WWF at Lucknow from 21-25 January 1997(Samant et al. 1998). Some examples of the endangered Himalayan medicinal plant species include: Aconitum balfourii, A.

deinorrhizum, Acorus calamus, Angelica glauca, Atropa belladonna, Berberis kashmiriana, Coptis teeta, Dioscorea deltoidea, Gentiana kurrooa, Nardostachys grandiflora, Picrorhiza kurrooa, Podophyllum hexandrum, Saussurea costus, Sweria chirayita and Taxus baccata subsp.wallichiana; and the sub-tropical/sub temperate species Aquilaria malaccensis. Drought stress is one of the most important environmental stress affecting agricultural productivity around the world and may result in considerable yield reductions (Boyer, 1982; Ludlow and Muchow, 1990).

Drought resistance refers to a plito groeproduc s atiy er ght ions, droacmation rs a abily slowly modify its structure and function so that it can better tolerate drought (Turner, 1986). A strategy for improving medicinal and aromatic plants yields is to identify the production compounds practices that are relatively drought resistant and that will result in superior yields under dry land conditions (Popp et al., 2002). Faced with scarcity of water resources, drought is the single most critical threat to world food security.

It was the catalyst of the great famines of the Be wowat supply is limiting, future food demand for rapidly increasing population pressures is likely to further aggravate the effects of drought (Somerville and Briscoe, 2001). Three main mechanisms reduce crop yield by soil water deficit: (i) reduced canopy absorption of photosynthetically active radiation, (ii) decreased radiation-use efficiency and (iii) reduced harvest index (Earl and Davis, 2003). Although plant responses to drought are relatively well known, plant performance under a more complex environment where multiple stresses co- occur is fragmentary. That is why the plants have to respond simultaneously to multiple stresses, e.g.

drought, excessive light and heat, which may coincide in the field. These kinds of investigations are usually not predictable from single factor studies (Zhou et al., 2007). Effects of drought stress on plant activities: The potentials of -10 to -15 more physiological phenomena such as leaf growth, stomatal conductance, photosynthetic rate and nitrogen metabolism decreases (Heidaiy and Moaveni, 2009). In the study of physiological phenomena of drought stress in plants, reported that the plant water status, often by measuring the water potential of tissues, specified by decreasing water potential decreases cell growth and protein synthesis.

The flow of carbon dioxide and leaf transpiration decreases, but the accumulation of

proline and abscisic acid stress increases (Heidaiy and Moaveni, 2009). Drought stress, photosynthesis by stomatal closure and transfer of carbon dioxide in chloroplasts and cell water potential decreased, affected. Drought stress, root and shoot growth is affected and may reduce the level of plants. Drought stress, crop yield reduces largely the following methods: 1- The reduction of photosynthetic active radiation absorbed by vegetation 2- reduce the efficiency of radiation 3- The reduction in harvest index.

Corn dry matter, the reduction in water consumption will decline (Sajedi, 2008). Medicinal plants under drought conditions: The effect of drought stress on medicinal plants growth and development has been studied lowly. The results were indicated that water deficit during the vegetative period (before flowering stage) can result in shorter plants and smaller leaf areas of mint (Abbaszadeh et al., 2008), yarrow (Sharifi Ashoorabadi et al., 2005) and chicory (Taheri et al., 2008), reduced water use due to the reduction in plant size of calendula (Rahmani et al., 2008), decreased vegetative dry matter of balm (Aliabadi et al., 2009).

Drought stress reduces yield of medicinal plants by three main mechanisms: First, whole canopy absorption of incident photosynthetically active radiation may be reduced, either by drought-induced limitation of leaf area expansion, by temporary leaf wilting or rolling during periods of severe stress, or by early leaf senescence. Second, drought stress decreased the efficiency with which absorbed photosynthetically active radiation is used by the crop to produce new dry matter (the radiation use efficiency). This can be detected as a decrease in the amount of crop dry matter accumulated per unit of photosynthetically active radiation absorbed over a given period of time, or as a reduction in the instantaneous whole- canopy net CO_2 exchange rate per unit absorbed photosynthetically active radiation. Third, drought stress may limit grain yield of medicinal plants by reducing the harvest index (HI).

This can occur even in the absence of a strong reduction in total medicinal plants dry matter accumulation, if a brief period of stress coincides with the critical developmental stage around flowering (Earl and Davis, 2003). Water deficit during the reproductive period can decrease the interval from seed formation to pollen shed and shorten the grain filling period. There also is a large amount of literature on the effect of water deficit on different medicinal plants yields components (Barnabas et al., 2007).

The numerous studies were indicated that grain yield can be drastically reduced as a result of water deficit during the reproductive period of coriander (Aliabadi et al., 2008), Mexican marigold (Mohamed et al., 2002) and grapevine (Scalabrelli et al., 2007). This grain yield reduction has been attributed to reduced grain number, grain weight, or both. Sinclair et al. (1990) attributed the greater sensitivity of grain yield to water deficit

at anthesis to this stage also being the period of maximum biomass accumulation and water use.

Consequently, drought stress reduced vegetative growth period and plant move to flowering stage. Therefore, quantity characteristics of medicinal plants decreased under drought conditions sorely. Essential oil content of medicinal plants under drought stress conditions An essential oil is a concentrated, hydrophobic liquid containing volatile aroma compounds from some plants. Essential oils do not as a group needs to have any specific chemical properties in common, beyond conveying characteristic fragrances. They are not to be confused with essential fatty acids. Essential oils are generally extracted by distillation.

Other processes include expression or solvent extraction. They are used in perfumes, cosmetics and bath products, for flavoring food and drink, and for scenting incense and household cleaning products (Sellar, 2001) Drought stress increases the essential oil percentage of medicinal plants. because in case of stress, more metabolites are produce in the plants and substances prevent from oxidization in the cells, but essential oil content reduce under drought stress, because the interaction between the amount of the essential oil percentage and shoot yield is consider important as two components of the essential oil content and by exerting stress, increases the essential oil percentage but shoot yield decreases by the drought stress, therefore essential oil content reduces (Aliabadi et al.,

2009). The effect of water stress on essential oil was studied in excised leafs of palmarosa (Cymbopogon martinii var. motia) and citronella java (C. winterianus). Essential oil percentage was increased under water stress and essential oil content was decreased under this condition (Fatima et al., 2006). An experiment was carried out to study the influence of water deficit stress on essential oil of balm. The results of this experiment showed that essential oil yield was reduced under water deficit stress but essential oil percentage was increased under stress (Aliabadi et al., 2009).

Also, Khalid (2006) evaluated the influence of water stress on essential oil of two species For both species under water stress, essential oil percentage and the main constituents of essential oil increased. Seventy five percent of field water capacity resulted in the highest yield of herb and essential oil for both species of an herb plant that is Ocimum basilicum L. (sweet basil) and Ocimum americanum L. (American basil). Singh- Sangwan et al. (2006) indicated that the level of essential oils was maintained or enhanced under drought condition. The major oil constituents, geraniol and citral increased substantially in two lemon grasses (Cymbopogon nardus and Cymbopogon pendulus).

Water stress had significant effect on flowering shoot yield, essential oil yield of flowering shoot and essential oil percentage of flowering shoot of coriander and highest upon characteristics were achieved under without stress conditions and highest oil percentage of flowering shoot was achieved under water stress conditions (Aliabadi et al., 2008). Consequently, drought stress reduces essential oil content of medicinal plants and increases essential oil percentage under drought conditions. Water use efficiency of medicinal plants under drought conditions Limited soil water availability reduces medicinal and aromatic plants growth more than all other environmental factors combined.

In arid and semi-arid regions where water resources for irrigation are being depleted, methods for more efficient irrigation scheduling are needed for commercial growers. The best option for medicinal plants production, yield improvement, and yield stability under soil moisture deficient conditions is to develop drought tolerant medicinal plants varieties. The potential soil moisture deficit produces two meaningful numbers: a critical deficit beyond which yield is reduced, and a reduction in yield per unit of potential deficit when the critical deficit is exceeded (Martin et al.,

2001) medicinal plants sorely, but increased the water use efficiency because, plants use available water in soil optimally. Also, plants decrease evapotranspiration by blocked or half-blocked of stomatals and reductions in leaf areas, plant height and lateral stem number. Therefore, water use efficiency of medicinal plants increases under drought conditions. Proline accumulation rate in medicinal plants under drought conditions: Drought stress results in an increase of proline biosynthesis rate.

Proline accumulation may in part involve induction and/or activation of enzymes of proline biosynthesis, possibly coupled with a relaxation of proline feedback inhibition control of the pathway, decreased proline oxidation to glutamate mediated at least in part by down regulation of proline dehydrogenase, decreased utilization of proline in protein synthesis and enhanced protein turnover. Water deficits induce dramatic increases in the proline concentration of phloem sap in medicinal plants, suggesting that increased deposition of proline at the root apex in water stressed plants could in part occur via phloem transport of proline.

A proline transporter gene, ProT2, is strongly induced by water and salt stress in Arabidopsis thaliana (Rentsch et al., 1996), Ketchum et al. (1991) suggest that translation but not transcription is necessary for production of proline in stressed cells. Stress-hypersensitive mutants of higher medicinal plants which exhibit disturbed proline metabolism can contribute significantly to the elucidation of the signals to which proline accumulation may respond. Petunias (Petunia hybrida cv. ') cumulfrproli (Pro) under

drought-stress conditions (Yamanda et al., 2005). A study was conducted to examine the response of date palm (Phoenix dactylifera L., cvs. Barhee and Hillali) calli to water stress. After 2 weeks, proline accumulation was assessed.

Increasing PEG concentration was also associated with a progressive reduction in water content and increased content of endogenous free proline (Al-Khayri and Al-Bahrany, 2004). Rehmannia glutinosa seedlings were pretreated with choline chloride (CC) in concentrations of 0, 0.7, 2.1 and 3.5 mM, and then subjected to drought and dewatering treatment to study the effect of CC on the proline accumulation. CC pretreatment accelerated accumulation of proline during drought stress and retarded the drop in proline concentration after dewatering. Consequently, 2.1 mM of CC is suitable for promoting proline accumulation of R.

glutinosa seedlings under drought stress (Zhao et al., 2007). Seedlings of two C. arabica genotypes (Catuai and BA10C1110- 10) with different drought tolerance levels were subject to controlled water stress. Proline content of secondary, tertiary and quarternary leaf pairs, from the apex, were evaluated. In both genotypes, the secondary leaf pair had higher proline content. Although proline levels increased with increased water deficit, it was not possible to distinguish between the two coffee seedlings in using this parameter.

Proline accumulation seemed to be related to injury imposed by water stress (Mazzafera and Teixeira, 2006). Baher et al. (2002) indicated proline accumulation of S. hortensis L. was increased under drought stress. Therefore, proline accumulation rate increases under drought conditions in medicinal plants sorely. Oxidative damage Exposure of plants to certain environmental stresses quite often leads to the generation of reactioxn superoxanion (O-2 hyl cals (OH), hydrogen peroxide (H2O2), alkoxy radicals (RO) and singlet oxygen (O1 2) (Munne-Bosch and Penuelas, 2003). Reactive oxygen species may react with proteins, lipids and deoxyribonucleic acid, causing oxidative damage and impairing the normal functions of cells (Foyer and Fletcher, 2001).

Many cell compartments produce reactive oxygen species; of these, chloroplasts are a potentially important source because excited pigments in thylakoid membranes may interact with O2 to form strong oxidants such as O-2 or O1 2 (Niyogi, 1999; Reddy et al., 2004). Further downstream reactions produce other reactive oxygen species such as H2O2 and .The interaction of O2 with reduced components of the electron transport chain in mitochondria can lead to reactive oxygen species formation (Moller, 2001), and peroxisomes produce H2O2 when glycolate is oxidized into glyoxylic acid during photorespiration (Fazeli et al., 2007). Accumulation materials such as carbohydrates and amino acids in plant cells that are called compatible solutes are known to play a role

(Ourcut and Nilsson, 2000).

Compatible soluble, low molecular weight compounds that interfere with cellular biochemical reactions normally do during osmotic stress, act as guards. In addition to the primary role in osmoregulation of these compounds may have an important role as protecting enzymes and membrane structure and eliminate active oxygen free radicals (Ourcut and Nilsson, 2000). Moisture reduction reactions such as protein degradation and accumulation of free amino acids in order to adjust the osmotic pressure of the cell followed (Bajji et al., 2001).

In situations where moderate or severe stress, increases the concentration of proline, proline as a nitrogen storage tank or soluble cytoplasmic osmotic potential decrease in acts of plant stress tolerance assists (Ghodsi et al, 1998). Chlorophyll is one of the major chloroplast components for photosynthesis (Rahdari et al, 2012). The decrease in chlorophyll content under drought stress has been considered a typical symptom of pigment photo oxidation and chlorophyll degradation (Anjum et al, 2011).

A decrease of total chlorophyll content with drought stress implies a lowered capacity for light harvesting. Since the production of reactive oxygen species is mainly driven by excess energy absorption in the photosynthetic apparatus, this might be avoided by degrading the absorbing pigments (Mafakheri et al, 2010). In relation to drought effect on chlorophyll a and b in leaf, we can express that drought is due to chloroplastic proteins hydrolysis, decreasing of leaf pigments and chlorophyll destruction as a primary stage in degradation of proteins (Synerri et al.,

1993). Drought stress tolerance mechanisms Drought Resistance in fact, the ability of species or cultivars for growth and production in drought conditions. By a long dry period on the physiological and morphological effects on yield and ultimate effect on yield depends on many factors. This not only depends on the time of drought on the life cycle of plants and water holding capacity of the soil in the root zone. It also depends on plant characteristics (Mohsenzadeh et al, 2006).

To prevent water losses, plants should close the stomatal, reducing absorption or decreased sweating, or a combination of all three levels will reduce the amount of transpiration (Shekari, 2000). With increasing water shortages, plants species can clog your pores. This reduces transpiration and especially when the stomatal are completely blocked and cuticular resistance is much truer. Active and inactive motion and increased leaf wax cracking or effective in reducing the absorption of radiation.

Active motion parallel to the incoming radiation leaves on the response to water

shortages for several plants has been observed (Rahmani, 2006). Drought stress causes to mentose or waxy leaves of some plants are both of these characteristics are reflected by the increasing amount of leaves to reduce water loss (Leila, 2007). One of drought tolerance in crop plants through water conservation and sustaining water absorption. The important feature is that this requires one to have deep roots and branches and a low resistance to flow of water inside the plant (Zareian, 2004).

Maintaining inflammation in the leaves while they are growing shortage of water can maintain the physiological activity. Maintaining inflammation in conditions of reduced leaf water potential can be fully or partially by setting the osmotic conditions, increase or decrease the size of the cell elasticity acquired (Shekari, 2000). Mechanisms to generate reactive oxygen species (ROS) Mechanisms for the generation of reactive oxygen species in biological systems are represented by both non-enzymatic and enzymatic reactions.

The partition between these two pathways under oxygen deprivation stress can be regulated by the oxygen concentration in the system. In non-enzymatic reactions, electron O2 reduction can occur at higher oxygen concentrations (Apel and Hirt, 2004). At very low O2 concentrations, plant terminal oxidases and the formation of reactive oxygen species via the mitochondrial electron transport chain still remain functional. Among enzymatic sources of reactive oxygen species, xanthine oxidase, an enzyme responsible for the initial activation of O2, should be mentioned.

The electron donor xanthine oxidase can use xanthine, hypoxanthine or acetaldehyde, while the latter has been shown to accumulate under oxygen deprivation (Pfister-Sieber and Braendle, 1994; Apel and Hirt, 2004). The next enzymatic step is the dismutation of the superoxide anion by superoxide dismutase to yield H2O2 (Lamb and Dixon, 1997). Peroxidases and catalases also play an important role in the fine regulation of reactive oxygen species in the cell through activation and deactivation of H2O2 (Sairam et al., 2005).

Several apoplastic enzymes may also generate reactive oxygen species under normal and stressful conditions. Other oxidases, responsible for the two-electron transfer to dioxygen (amino acid oxidases and glucose oxidase) can contribute to H2O2 accumulation (Apel and Hirt, 2004). Reactive oxygen species are formed as by-products in the electron transport chains of chloroplasts (Apel and Hirt, 2004), mitochondria and the plasma membrane (Sairam et al., 2005).

The plant mitochondrial electron transport chain, with its redox-active electron carriers, is considered as the most probable candidate for intracellular reactive oxygen species

formation. Mitochondria can produce reactive oxygen species due to the electron leakage at the ubiquinone site – the ubiquinone: cytochrome b region (Gille and Nohl, 2001) – and at the matrix side of complex I (NADH dehydrogenase) (Moller, 2001). Superoxide radical and its reduction product H_2O_2 are potentially toxic compounds, and can also combine by the Haber-Weiss reaction to form the highly toxic OH - (Sairam et al., 1998).

Many reports show the deleterious effects of reactive oxygen species, whose production is stimulated under water, stress (Blokhina et al., 2003). Reactive oxygen species cause lipid peroxidation, and consequently membrane injuries, protein degradation and enzyme inactivation (Sairam et al., 2005). Oxidative stress may also cause protein oxidation, with a loss of enzyme activity and the formation of protease resistant cross-linked aggregates (Berlett and Stadtman, 1997).

Overall, the production of reactive oxygen species is linear with the severity of drought stress, which leads to enhanced peroxidation of membrane lipids and degradation of nucleic acids, and both structural and functional proteins. Various organelles including chloroplasts, mitochondria and peroxisomes are the seats as well as first target of reactive oxygen species produced under drought stress. Drought resistance mechanisms Plants respond and adapt to survive under drought stress by the induction of various morphological, biochemical and physiological responses.

Drought tolerance is defined as the ability to grow, flower and display economic yield under suboptimal water supply. Drought stress affects the water relations of plants at cellular, tissue and organ levels, causing specific as well as unspecific reactions, damage and adaptation reactions (Beck et al., 2007). To cope with the drought, tolerant plants initiate defense mechanisms against water deficit (Chaves and Oliveira, 2004), which need to be investigated in further detail (Zhou et al., 2007).

Morphological mechanisms Plant drought tolerance involves changes at whole-plant, tissue, physiological and molecular levels. Manifestation of a single or a combination of inherent changes determines the ability of the plant to sustain itself under limited moisture supply. An account of various morphological mechanisms operative under drought conditions is given below. Escape Escape from drought is attained through a shortened life cycle or growing season, allowing plants to reproduce before the environment becomes dry.

Flowering time is an important trait related to drought adaptation, where a short life cycle can lead to drought escape (Araus et al., 2002). Crop duration is interactively determined by genotype and the environment and determines the ability of the crop to

escape from climatic stresses including drought (Dingkuhn and Asch, Dingkuhn). Matching growth duration of plants to soil moisture availability is critical to realize high seed yield (Siddique et al., 2003).

Drought escape occurs when phenological development is successfully matched with periods of soil moisture availability, where the growing season is shorter and terminal drought stress predominates (Araus et al., 2002). In field- grown clones of robusta coffee, leaf shedding in response to drought stress occurred sequentially from older to younger leaves, suggesting that the more drought-sensitive the clone, the greater the extent of leaf shedding (DaMatta, 2004). Time of flowering is a major trait of a crop adaptation to the environment, particularly when the growing season is restricted by terminal drought and high temperatures.

Developing short-duration varieties has been an effective strategy for minimizing yield loss from terminal drought, as early maturity helps the crop to avoid the period of stress (Kumar and Abbo, 2001). However, yield is generally correlated with the length of crop duration under favorable growing conditions, and any decline in crop duration below the optimum would tax yield (Turner et al., 2001). Avoidance Drought avoidance consists of mechanisms that reduce water loss from plants, due to stomatal control of transpiration, and also maintain water uptake through an extensive and prolific root system (Turner et al., 2001; Kavar et al., 2007).

The root characters such as biomass, length, density and depth are the main drought avoidance traits that contribute to final yield under terminal drought environments (Subbarao et al., 1995; Turner et al., 2001). A deep and thick root system is helpful for extracting water from considerable depths (Kavar et al., 2007). Glaucousness or waxy bloom on leaves helps with maintenance of high tissue water potential, and is therefore considered as a desirable trait for drought tolerance (Richards et al., 1986; Ludlow and Muchow, 1990).

Varying degrees of glaucousness in wheat led to increased water- use efficiency, but did not affect total water use or harvest index. Determination of leaf temperature indicated that, compared with non-glaucous leaves, glaucous leaves were 0.7 ? C cooler and had a lower rate of leaf senescence (Richards et al., 1986). Phenotypic flexibility Plant growth is greatly affected by water deficit. At a morphological level, the shoot and root are the most affected and both are the key components of plant adaptation to drought.

Plants generally limit the number and area of leaves in response to drought stress just to cut down the water budget at the cost of yield loss (Schuppler et al., 1998). Since roots are the only source to acquire water from soil, the root growth, its density,

proliferation and size are key responses of plants to drought stress (Kavar et al., 2007). It has long been established that plants bearing small leaves are typical of xeric environments. Such plants withstand drought very well, albeit their growth rate and biomass are relatively low (Ball et al., 1994).

Leaf pubescence is a xeromorphic trait that helps protect the leaves from excessive heat load. Hairy leaves have reduced leaf temperatures and transpiration (Sandquist and Ehleringer, 2003) whilst inter- and intra-specific variation exists for the presence of this trait. Under high temperature and radiation stress, hairiness increases the light reflectance and minimizes water loss by increasing the boundary layer resistance to water vapor movement away from the leaf surface.

Although drought stress also induces the production of trichomes on both sides of wheat leaves, they had no significant influence on boundary layer resistance. The water content in drought-treated mature stems declined by 4% and water potential by – 0.25 MPa. It is shown that active phloem supply of assimilates and associated water reserves from mature stems was the mechanism that allowed developing stems of Hylocereus undatus to maintain growth under drought conditions (Nerd and Neumann, 2004). Moreover, girdling the phloem of growing stems rapidly inhibited stem elongation, but secretion of sucrose-containing nectar was maintained during drought.

The water potential gradient was in the wrong direction for xylem transport from mature to young growing stems and axial hydraulic conductivity was low to negligible (Nerd and Neumann, 2004). Roots are the key plant organ for adaptation to drought. If tolerance is defined as the ability to maintain leaf area and growth under prolonged vegetative stage stress, the main basis of variation appears to be constitutive root system architecture that allows the maintenance of more favorable plant water status (Nguyen et al., 1997). The possession of a deep and thick root system allowed access to water deep in the soil, which was considered important in determining drought resistance in upland rice (Kavar et al., 2007).

To summarize, plants may escape drought stress by cutting short their growth duration, and avoid the stress with the maintenance of high tissue water potential either by reducing water loss from plants or improved water uptake, or both. Some plants may reduce their surface area either by leaf shedding or production of smaller leaves. Physiological mechanisms Osmotic adjustment, osmoprotection, antioxidation and a scavenging defense system have been the most important bases responsible for drought tolerance.

The physiological basis of genetic variation in drought response is not clear; in part,

because more intricate mechanisms have been suggested. Water conservation through Cell and tissue Under drought stress, sensitive pea genotypes were more affected by a decline in relative water content than tolerant ones (Upreti et al., 2000). In faba bean, determination of leaf water potential was useful for describing the drought effect, but was not suitable for discriminating tolerant from sensitive genotypes.

This suggested that water potential was not the defining feature of the tolerance (Riccardi et al., 2001). Nevertheless, other studies opined that determination of leaf water status in the morning and water content in leaves in the afternoon were potentially useful for screening drought tolerance in chickpea (Pannu et al., 1993). Osmotic adjustment allows the cell to decrease osmotic potential and, as a consequence, increases the gradient for water influx and maintenance of turgor.

Improved tissue water status may be achieved through osmotic adjustment and/or changes in cell wall elasticity. This is essential for maintaining physiological activity for extended periods of drought (Kramer and Boyer, 1995). Wild melon plant survived drought by maintaining its water content without wilting of leaves even under severe drought. Drought stress in combination with strong light led to an accumulation of high concentrations of citrulline, glutamate and arginine in leaves of wild watermelon.

The accumulation of citrulline and arginine may be related to the induction of dopamine receptor interacting protein gene 1, a homologue of the acetylornithine deacetylase gene in Escherichia coli, where it functions to incorporate the carbon skeleton of glutamate into the urea cycle (Yokota et al., 2002). It has been identified that among various mechanisms, osmotic adjustment, abscisic acid and induction of dehydrins may confer tolerance against drought injuries by maintaining high tissue water potential (Turner et al., 2001).

With the accumulation of solutes, the osmotic potential of the cell is lowered, which attracts water into the cell and helps with turgor maintenance. The maintenance of turgor despite a decrease in leaf water volume is consistent with other studies of species with elastic cell walls. Osmotic adjustment helps to maintain the cell water balance with the active accumulation of solutes in the cytoplasm, thereby minimizing the harmful effects of drought (Morgan, 1990).

Osmotic adjustment is an important trait in delaying dehydrative damage in water-limited environments by continued maintenance of cell turgor and physiological processes (Taiz and Zeiger, 2006). The osmotic adjustment also facilitates a better translocation of pre-anthesis carbohydrate partitioning during grain filling (Subbarao et al., 2000), while high turgor maintenance leads to higher photosynthetic rate and

growth (Ludlow and Muchow, 1990; Subbarao et al., 2000).

Antioxidant defense mechanism The antioxidant defense system in the plant cell constitutes both enzymatic and non-enzymatic components. Enzymatic components include superoxide dismutase, catalase, peroxidase, and ascorbate peroxidase and glutathione reductase. Non-enzymatic components contain cysteine, reduced glutathione and ascorbic acid (Gong et al., 2005). In environmental stress tolerance, such as drought, high activities of antioxidant enzymes and high contents of non-enzymatic constituents are important. The reactive oxygen species in plants are removed by a variety of antioxidant enzymes and/or lipid-soluble and water soluble scavenging molecules (Hasegawa et al.,

2000); the antioxidant enzymes being the most efficient mechanisms against oxidative stress (Farooq et al., 2008). Apart from catalase, various peroxidases and peroxiredoxins, four enzymes are involved in the ascorbate-glutathione cycle, a pathway that allows the scavenging of superoxide radicals and H_2O_2. These include ascorbate peroxidase, dehydroascorbate reductase, monodehydroascorbate reductase and glutathione reductase (Fazeli et al., 2007).

Most of the ascorbate glutathione cycle enzymes are located in the cytosol, stroma of chloroplasts, mitochondria and peroxisomes (Jimenez et al., 1998). Ascorbate peroxidase is a key antioxidant enzyme in plants (Orvar and Ellis, 1997) whilst glutathione reductase has a central role in maintaining the reduced glutathione pool during stress (Pastori et al., 2000). Two glutathione reductase complementary deoxyribonucleic acids have been isolated; one type encoding the cytosolic isoforms (Stevens et al.,

2000) and the other encoding glutathione reductase proteins dual-targeted to both chloroplasts and mitochondria in different plants (Chew et al., 2003). Among enzymatic mechanisms, superoxide dismutase plays an important role, and catalyzes the dismutation of two molecules of superoxide into O_2 and H_2O_2; the first step in reactive oxygen species scavenging systems. Lima et al. (2002), from a study utilizing two rapidly drought- stressed clones of Coffea canephora, proposed that drought tolerance might, or at least in part, be associated with enhanced activity of antioxidant enzymes. In contrast, Pinheiro et al.

(2004) did not find a link between protection against oxidative stress and drought tolerance when four clones of C. canephora were subjected to long-term drought. Carotenoids and other compounds, such as abietane diterpenes, have received little attention despite their capacity to scavenge singlet oxygen and lipid peroxy-radicals, as well as to inhibit lipid peroxidation and superoxide generation under dehydrative forces

(Deltoro et al., 1998).

The transcript of some of the antioxidant genes such as glutathione reductase or ascorbate peroxidase was higher during recovery from a water deficit period and appeared to play a role in the protection of cellular machinery against damage by reactive oxygen species (Ratnayaka et al., 2003). A superoxide radical has a half-life of less than 1 sec and is rapidly dismutated by superoxide dismutase into H2O2, a product that is relatively stable and can be detoxified by catalase and peroxidase (Apel and Hirt, 2004).

These metalloenzymes constitute an important primary line of defense of cells against superoxide free radicals generated under stress conditions. Therefore, increased superoxide dismutase activity is known to confer oxidative stress tolerance (Pan et al., 2006). Oxidative damage in the plant tissue is alleviated by a concerted action of both enzymatic and non-enzymatic antioxidant sThese de -carotenes, ascorbic acid, a -tocopherol, reduced glutathione and enzymes including superoxide dismutase, peroxidase, ascorbate peroxidase, catalase, polyphenol oxidase and glutathione reductase (Hasegawa et al., 2000; Prochazkova et al., 2001).

Carotenes form a key part of the plant antioxidant defense system (Havaux, 1998; Wahid, 2007), but they are very susceptible to oxidative destruction. The - carotene present in the chloroplasts of all green plants is exclusively bound to the core complexes of photosystem I and photosystem II. Protection against damaging effects of reactive oxygen species at this site is essential foast functi He -carotene, in addition to functioning as an accessory pigment, acts as an effective antioxidant and plays a unique role in protecting photochemical processes and sustaining them (Havaux, 1998). A major protective role of -carotene in photosynthetic tissue may be through direct quenching of triplet chlorophyll, which prevents the generation of singlet oxygen and protects from oxidative damage.

Stability of Cell membrane Biological membranes are the first target of many abiotic stresses. It is generally accepted that the maintenance of integrity and stability of membranes under water stress is a major component of drought tolerance in plants (Bajji et al., 2002). Cell membrane stability, reciprocal to cell membrane injury, is a physiological index widely used for the evaluation of drought tolerance (Premachandra et al., 1991).

Moreover, it is a genetically related phenomenon since quantitative trait loci for this have been mapped in drought-stressed rice at different growth stages (Tripathy et al., 2000). Dhanda et al. (2004) showed that membrane stability of the leaf segment was the

most important trait to screen the germplasm for drought tolerance. Cell membrane stability declined rapidly in Kentucky bluegrass exposed to drought and heat stress simultaneously (Wang and Huang, 2004).

In a study on maize, K nutrition improved the drought tolerance, mainly due to improved cell membrane stability (Gnanasiri et al., 1991). Tolerance to drought evaluated as increase in cell membrane stability under water deficit conditions was differentiated between cultivars and correlated well with a reduction in relative growth rate under stress (Premachandra et al., 1991). In holm oak (Quercus ilex) seedlings, hardening increased drought tolerance primarily by reducing osmotic potential and stomatal regulation, improved new root growth capacity and enhanced cell membrane stability.

Among treated seedlings, the greatest response occurred in seedlings subjected to moderate hardening. Variation in cell membrane stability, stomatal regulation and root growth capacity was negatively related to osmotic adjustment (Villar-Salvador et al., 2004). The causes of membrane disruption are unknown; notwithstanding, a decrease in cellular volume causes crowding and increases the viscosity of cytoplasmic components. This increases the chances of molecular interactions that can cause protein denaturation and membrane fusion. For model membrane and protein systems, a broad range of compounds have been identified that can prevent such adverse molecular interactions.

Some of these are proline, glutamate, glycinebetaine, carnitine, mannitol, sorbitol, fructans, polyols, trehalose, sucrose and oligosaccharides (Folkert et al., 2001). Another possibility of ion leakage from the cell may be due to thermal induced inhibition of membrane- bound enzymes responsible for maintaining chemical gradients in the cell (Reynolds et al., 2001). Arabidopsis leaf membranes appeared to be very resistant to water deficit, as shown by their capacity to maintain polar lipid contents and the stability of their composition under severe drought (Gigon et al., 2004).

Osmotic adjustment and Compatible solutes One of the most common stress tolerance strategies in plants is the overproduction of different types of compatible organic solutes (Serraj and Sinclair, 2002). Compatible solutes are low- molecular-weight; highly soluble compounds that are usually nontoxic even at high cytosolic concentrations. Generally they protect plants from stress through different means such as contribution towards osmotic adjustment, detoxification of reactive oxygen species, stabilization of membranes, and native structures of enzymes and proteins.

Osmotic adjustment is a mechanism to maintain water relations under osmotic stress. It involves the accumulation of a range of osmotically active molecules/ions including

soluble sugars, sugar alcohols, proline, glycinebetaine, organic acids, calcium, potassium, chloride ions, etc. Under water deficit and as a result of solute accumulation, the osmotic potential of the cell is lowered, which attracts water into the cell and helps with the maintenance of turgor.

By means of osmotic adjustment, the organelles and cytoplasmic activities take place at about a normal pace and help plants to perform better in terms of growth, photosynthesis and assimilate partitioning to grain filling (Ludlow and Muchow, 1990; Subbarao et al., 2000). As a mechanism, osmotic adjustment has been suggested as an important trait in postponing the dehydration stress in water scarce environments (Morgan, 1990). Variation in osmotic adjustment among chickpea cultivars in response to soil drought has been observed, and seed yield of chickpea was correlated with the degree of osmotic adjustment when grown under a line-source irrigation system in the field (Moinuddin and Khannu-Chopra, 2004). Osmotic adjustment is accomplished with the accumulation of compatible solutes.

Of these, proline is one amongst the most important cytosolutes and its free accumulation is a widespread response of higher plants, algae, animals and bacteria to low water potential (Zhu, 2002; Wahid and Close, 2007). Its synthesis in leaves at low water potential is caused by a combination of increased biosynthesis and slow oxidation in mitochondria. Despite some controversy, many physiological roles have been assigned to free proline including stabilization of macromolecules, a sink for excess reductant and a store of carbon and nitrogen for use after relief of water deficit (Zhu, 2002).

Proline contents were increased under drought stress in pea cultivars (Alexieva et al., 2001). Drought-tolerant petunia (Petunia hybrida) varieties were reported to accumulate free proline under drought that acted as an osmoprotectant and induced drought tolerance (Yamada et al., 2005). Glycinebetaine (N, N, N-trimethyl glycine) is one of the most extensively studied quaternary ammonium compounds and compatible solutes in plants, animals and bacteria (Wahid et al., 2007).

Many studies demonstrate that glycinebetaine plays an important role in enhancing plant tolerance under a range of abiotic stresses including drought (Quan et al., 2004). The introduction of genes synthesizing glycinebetaine into non-accumulators of glycinebetaine proved to be effective in increasing tolerance to various abiotic stresses (Sakamoto and Murata, 2002). Naidu et al. (1998) reported that cotton cultivars adapted to water stress conditions accumulated higher glycine betaine than the non-adapted ones under drought.

In addition to direct protective roles of glycinebetaine either through positive effects on enzyme and membrane integrity or as an osmoprotectant, glycinebetaine may also protect cells from environmental stresses indirectly by participating in signal transduction pathways (Subbarao et al., 2000). Citrulline, named after Citrullus; a Latin name of watermelon, from which it was isolated, is an amino acid. Although not built into proteins during their synthesis, and not encoded by a nuclear gene, several proteins are known to contain citrulline (Kawasaki et al., 2000).

Wild watermelon (Citrullus lanatus) has the ability to adapt to severe drought stress despite carrying out normalnC3-type photosynthesis, which seem to be correlated with citrulline accumulation (Akashi et al., 2001). Wild watermelon primarily accumulated citrulline followed by glutamate and arginine, in place of proline and glycinebetaine (Kawasaki et al., 2000). Yokota et al. (2002) reported a higher citrulline accumulation in the wild watermelon leaves assuming that citrulline is located only in the cytosol and constitutes 5% of the total volume of the mesophyll cells.

Citrulline is a novel and the most effective OH - scavenger among compatible solutes examined so far. Moreover, it can effectively protect DNA and enzymes from oxidative injuries (Akashi et al., 2001; Bektasoglu et al., 2006). Rapid accumulation of the non-protein no id -aminobutyric acid was identified in plant tiupon posure stress y ars go. -aminobutyric acid acts as a zwitterion, exists in free form, and has a flexible molecule that can assume several conformations in solution, including cc re is ilto ne. phoal ? -aminobutyric acid is highly water-soluble (Shelp et al.,

1999), and may function as a signaling molecule in higher plants under stress (Serraj et al., 1998). The physiological roles of ? -aminobutyric acid in drought tolerance entail osmotic regulation (Shelp et al., 1999), detoxication of reactive oxygen radicals, conversion of putrescine into proline and intracellular signal transduction (Kinnersley and Turano, 2000). Drought stress initiates a signal transduction pathway, in which increased cytosolic Ca2+activates Ca2+/ calmdependent amate caylactiy, ading o -aminobutyric acid synthesis (Shelp et al., 1999).

Elevated H+ and substrate levels can also stimulate glutamate decarboxase vit eadinprimrilto? -aminobutyric acid accumulation. Experimental evidence the vement ? -aminobutyric acid in pH regulation, nitrogen storage, plant development and defense, as well as a compatible osmolyte and an alternative pathway for glutamate utilization (Shelp et al., 1999; Wahid et al., 2007). After drought stress the content of proline was more than 50% and at the oreoverthe -aminobutyric acid content reached 27% (Simon-sarkadi et al., 2006).

Trehalose is a non-reducing disaccharide of glucose that functions as a compatible solute in the stabilization of biological structures under abiotic stress (Goddijn et al., 1997). In nature, trehalose is biosynthesized as a stress response by a variety of organisms including bacteria, fungi, algae, insects, invertebrates and lower plants (Wingler, 2002). Capacity to produce trehalose, earlier thought to be absent from higher plants, has now been reported to accumulate in high amounts in some drought-tolerant ferns, the resurrection plant Selaginella lepidophylla (Penna, 2003) and desiccation-tolerant angiosperm Myrothamnus flabellifolia (Drennan et al., 1993). The presence of low amounts of trehalose was demonstrated even in tobacco (Goddijn et al., 1997) and many higher plants (Kosmas et al., 2006).

Its metabolism may be channelized to enhance drought tolerance in plants (Pilon-Smits et al., 1998; Penna, 2003). Physiological roles of trehalose include efficient stabilization of dehydrated enzymes, proteins and lipid membranes, as well as protection of biological structures under desiccation stress (Wingler, 2002) rather than regulating water potential (Lee et al., 2004). Karim et al. (2007) reported that enhanced drought tolerance by trehalose depends on improved water status and expression of heterologous trehalose biosynthesis genes during Arabidopsis root development.

At a molecular level, exogenously applied trehalose may trigger the abscisic acid-insensitive 4 gene expression but decrease sucrose induction, providing a possible molecular mechanism for the trehalose effect on plant gene expression and growth (Ramon et al., 2007). Trehalose-accumulating organisms produce this sugar in a two-step process by the action of the enzymes trehalose-6-phosphate synthase and trehalose-6-phosphate phosphatase when exposed to stress. Improved drought tolerance has been reported in the transgenic plants overproducing trehalose-6-phosphate synthase in spite of minute accumulation of trehalose (Karim et al., 2007).

In fact, plants can withstand drought stress by conserving cell and tissue water principally by osmatic adjustment, maintenance of the antioxidant defense system for the scavenging of reactive oxygen species, and keeping the cell membranes stabilized. Plant growth regulators and polnes, - aminobutyric acid, free amino acids and sugars also play a vital role in drought tolerance by scavenging the reactive oxygen species, stomatal regulation and protection of vital macromolecules, and maintenance of the cell water balance. Use of osmoprotectants Osmoprotectants are involved in signaling and regulating plant responses to multiple stresses, including reduced growth t hat y e art f adast .

In plants, the common osmoprotectants are proline, trehalose, fructan, mannitol,

glycinebetaine and others (Zhu, 2002). They play adaptive roles in mediating osmotic adjustment and protecting subcellular structures in stressed plants. However, not all plants accumulate these compounds in sufficient amounts to avert adverse effects of drought stress (Penna, 2003). Ashraf and Foolad (2007) outlined three approaches to increase the concentrations of these compounds in plants grown under stress conditions to increase their stress tolerance: (1) use of traditional protocols of plant genetics and breeding to develop cultivars with natural abilities to produce high levels of these compounds under stress conditions, (2) engineering genetically modified plants capable of producing sufficient amounts of these compounds in response to environmental stresses and (3) as a short-cut method, exogenous use of these osmolytes on plants to enhance their stress tolerance ability. Exogenously applied glycinebetaine improves the growth and production of some plants under stress (Naidu et al., 1998; Chen et al.,

2000; Hussain et al., 2008). In many crop plants the natural accumulation of glycinebetaine is lower than sufficient to ameliorate the adverse effects of dehydration caused by various environmental stresses (Subbarao et al., 2000). Exogenous application of glycinebetaine has been reported to improve drought tolerance in this regard (Hussain et al., 2008). Foliar-applied glycinebetaine improved the growth of plants subjected to water deficit by the maintenance of leaf water status due to improved osmotic adjustment and enhanced photosynthesis, primarily due to a greater stomatal conductance and carboxylation efficiency of Rubisco (Sakamoto and Murata, 2002). Exogenous application of glycinebetaine effectively diminished the drought effects in terms of greater number of achenes per capitulum in sunflower (Azam et al., 2005).

However, pre-soaking of seeds with glycinebetaine was not effective in preventing the adverse effects of water stress on yield components. Glycinebetaine application at the vegetative stage was more effective in ameliorating the adverse effects of drought (Azam et al., 2005). Glycinebetaine also increased anti-oxidative enzyme activities under water deficit (Ma et al., 2007). Exogenously applied proline enhanced the endogenous accumulation of free proline and improved the drought tolerance in petunia (Yamada et al., 2005).

Inhibitors of polyamine biosynthetic enzymes limit stress tolerance of wheat but the concomitant exogenous application of polyamines restores it (Liu et al., 2004). Exogenous spermidine application before the drought stress significantly improved the stress tolerance in barley (Kubi´s, 2003). In a recent review, Liu et al. (2007) concluded that though there was variation in effects between polyamines and plant species, exogenous polyamine application to stressed cells or tissues could lead to injury alleviation and growth promotion. Yang et al.

(2007) suggested that for rice, to perform well under drought stress, it should have higher levels of free spermidine/free spermine and insoluble-conjugate putrescine. Conclusion Frequent drought is the major consequence of global climate change. Physiological, biochemical, molecular changes occur in plant during stress condition. Low water availability reduces metabolic process such as water and mineral absorption, rate of photosynthesis, dry matter production and yield. Oxidative damage of cellular organization occurs during drought stress by the production of reactive oxygen species. Plant has specific innate anti-oxidant mechanism to mitigate the effect of water stress.

Physiological changes make plants resistant to drought stress. Some chemicals with antioxidant property are also involved in mitigation of drought stress by changing physiological paradigms. References 1. Abbaszadeh B, Sharifi Ashoorabadi E, Ardakani MR, Aliabadi FH (2008). Effect of drought stress on quantitative and qualitative of mint. Abstracts Book of 5th International Crop Science Congress & Exhibition, Korea p. 23. 2. Aliabadi FH, Lebaschi MH, Hamidi A (2008). Effects of arbuscular mycorrhizal fungi, phosphorus and water stress on quantity and quality characteristics of coriander. J. Adv. Nat. Appl. Sci. 2(2): 55-59. 3.

Aliabadi FH, Lebaschi MH, Shiranirad AH, Valadabadi AR, Daneshian J (2008). Effects of arbuscular mycorrhizal fungi, different levels of phosphorus and drought stress on water use efficiency, relative water content and proline accumulation rate of coriander (Coriandrum sativum L.). J. Med. Plant. Res. 2(6): 125-131. 4. Aliabadi FH, Valadabadi SAR, Daneshian J, Khalvati MA (2009). Evaluation changing of essential oil of balm (Melissa officinalis L.) under water deficit stress conditions. J. Med. Plant. Res. 3(5): 329 – 33. 5. Al-Khayri JM, Al-Bahrany AM (2004).

Growth, water content, and proline accumulation in drought-stressed callus of date palm. Bio. Planta 48(1): 105-108. 6. Baher Z, Mirza M, Ghorbanli M, Rezaii MB (2002). The influence of water stress on plant height, herbal and essential oil yield and composition in Satureja hortensis L. Flav. Frag. J., 17(4): 275-277. 7. Bajji, M., Lutts, S., & Kinet, J.-M. (2001). Water deficit effects on solute contribution to osmotic adjustment as a function of leaf ageing in three durum wheat (Triticum durum Desf.) cultivars performing differently in arid conditions. Plant Science, 160(4), 669-681. 8.

Barnabas B, Jager K, Feher A (2007). The effect of drought and heat stress on reproductive processes in cereals. Plant Cell Environ. 31(1): 11-38. 9. Blum A (1988). Plant breeding for stress environments. CRC Press, Boca Raton, Florida, USA pp: 1-223. Boyer JS (1982). Plant productivity and environment. Sci. 218: 443-448. 10. Earl H, Davis RF (2003). Effect of drought stress on leaf and whole canopy radiation use efficiency and

yield of maize. Agron. J. 95:688- 696. 11. Fatima S, Farooqi AHA, Sangwan RS (2006). Water stress mediated modulation in essential oil, proline and polypeptide profile in palmarosa and citronella java. Physiology and Molecular Biology of Plants.

Central Institue of Medicinal and Aromatic Plants, P.O. CIMAP, Lucknow - 226 015, India. 12. Ghodsi, M., M. Nuzeri and A. Zarea-Fizabady. 1998. The reaction of new cultivars and Alite lines on spring wheat into drought stress, Collection of abstract articles of 5 th Iranian agronomy and plant breeding conference, Karaj, Iran. 252p. 13. Heidaiy, Y and Moaveni, p. 2009. Study of Drought stress on accumulation and proline among aba in different genotypes forage corn .Research journal of biological sciences.4:1121-1124. 14. Ketchum REB, Warren RC, Klima LJ, Lopez-Gutierrez F, Nabors MW (1991).

The mechanism and regulation of proline accumulation in suspension cultures of the halophytic grass Distichlis spicata L. J. Plant Physiol. 137: 368-374. 15. Khalid KhA (2006). Influence of water stress on growth, essential oil, and chemical composition of herbs (Ocimum sp.). Int. Agrophys. 20(4): 289-296. 16. Kramer PJ, Boyer JS (1995). Water Relations of Plants and Soils. Academic press, San Diego, USA pp: 1-495. Kucharski WA, Mordaiski R (2008). The compasion of efficiency of tillage coriander in conventional and ecological system. J. Res. Appl. Agric. Eng. 53(3): 152- 155. 17. Leila, R. 2007.

Response of Tunisian autochthonous peral millet to drought stress induced by polyethylene glycol 6000. African Journal of Biotechnology. 6: 1102-1105. 18. Ludlow MM, Muchow RC (1990). A critical evaluation of the traits for improving crop yield in water limited environments. Adv. Agron. 43:107 – 153. 19. Mafakheri A, Siosemardeh A, Bahramnejad B, Struik PC, Sohrabi Y, 2010. Effect of drought stress on yield, proline and chlorophyll content in three Chickpea cultivars. J. Australian Crop Sci., 4(8): 580-585. 20. Martin RJ, Jamieson PD, Gillespie RN, Maley S (2001).

Effect of timing and intensity of drought on the yield of Oats (Avena sativa L.). Proceedings of the 10th Australian Agronomy Conference. 21. Mohamed MAH, Harris PJC, Henderson J, Senatore F (2002). Effect of drought stress on the yield and composition of volatile oils of drought tolerant and non-drought-tolerant clones of Tagetes minuta. Planta medica. 68(5): 472-474. 22. Mohsenzadeh S, Malboobi MA, Razavi K, Farrahi-Ashtiani (2006) Physiological and molecular responses of Aeluropus lagopoides (poaceae) to water stress. Environ Exp Bot 56: 314-322. 23. Ourcut, D. and Nilsen, E. T. 2000. Salinity and drought stress.

In Physiology of plants under Stress. KA/PP: 177-235.Terlestkaya, N. 2000. Water stress. American Society of Plant Biologist. 24. Popp MP, Keisling TC, McNew RW, Oliver LR, Dillon CR, Wallace DM (2002). Planting date, cultivar, and tillage system effects on dry

land soybean production. Agric. J. 94: 81-88. 25. Rahdari P, Hoseini SM, Tavakoli S, 2012. The studying effect of drought stress on germination, proline, sugar, lipid, protein and chlorophyll content in Purslane (Portulaca oleraceae L.) leaves. J. of Medicinal Plants. Res., Vol. 6(9): 1539-1547. 26.

Rahmani N, Aliabadi Farahani H, Valadabadi SAR (2008) Effects of nitrogen on oil yield and its component of Calendula (Calendula officinalis L.) in drought stress conditions. Abstracts Book of The world congress on medicinal and aromatic plants, South Africa p.364. 27. Rahmani, N. 2006. Effect of irrigation and nitrogen application on the quantity and quality of medicinal plant Marigold (Calendula Officinalis L.). Master Thesis Agronomy, University of Takestan Branch. Responses of plants to drought stress. J. African. Agri. Res., Vol. 6(9): 2026-2032. 28. Rentsch D, Hirner B, Schmeizer E, Frommer WB (1996).

Salt stress induced proline transporters and salt stress-repressed broad specificity amino acid permeases identified by suppression of a yeast amino acid permease-targeting mutant. Plant Cell 8:1437-1446. 29. Sajedi, N. and Sajedi. AS., 2008, Effect of drought stress on physiological characteristics of maize mycorrhiza and zinc. Journal of Crop Science. Volume 11, No. 3, p. 202 to 222. 30. Scalabrelli G, Saracini E, Remorini D, Massai R, Tattini M (2007). Changes in leaf phenolic compounds in two grapevine varieties (Vitis vinifera L.) grown in different water conditions. Acta Hort. 754: 295- 300. 31. Sharifi Ashoorabadi E, Matin M, Lebaschi H, Abbaszadeh B, Naderi B (2005).

Effects of water stress on quantity yield in Achillea millefolium. Abstracts Book of The First International Conference on the Theory and Practices in Biological Water Saving p.211. 32. Shekari, F. 2000. Effect of drought stress on phenology, water relations, growth, yield and quality canola, doctorate thesis in the field of Agriculture, University of Tabriz, p.180. 33. Singh-Sangwan N, Farooqi AHA, Singh-Sangwan R (2006). Effect of drought stress on growth and essential oil metabolism in lemon grasses. New Phytol. 128(1): 173 – 179. 34. Synerri CLM, Pizino C, Navariizzo F, 1993. Chemical changes and O2 production in thylakoid membrane under water stress. Plant Physiol.,

87: 211-216. 35. Taheri AM, Daneshian J, Valadabadi SAR, Aliabadi FH (2008). Effects of water deficit and plant density on morphological characteristics of chicory (Cichorium intybus L.). Abstracts Book of 5thInternational Crop Science Congress & Exhibition p.26. 36. Tripathy J.N., Zhang J., Robin S., Nguyen T.T., Nguyen H.T. (2000) QTLs for cell-membrane stability mapped in rice (Oryza sativa L.) under drought stress, The or. Appl. Genet. 100, 1197 – 1202. 37. Turner NC (1986). Crop water deficits: a decade of progress. Adva. Agro. 39: 1-51. 38. Yamada M, Morishita H, Urano K, Shiozaki N, Yamaguchi-Shinozaki K, Shinozaki K, Yoshiba Y (2005).

Effects of free proline accumulation in petunias under drought stress. J. Exp. Bot. 56(417):1975-1981. 39. Pfister-Sieber M., Braendle R. (1994) Aspects of plant behavior under anoxia and post- anoxia, Proc. R. Soc. Edinburgh 102B, 313 – 324. 40. Pilon-Smits E.A.H., Terry N., Sears T., Kim H., Zayed A., Hwang S.B., Van Dun K., Voogd E., Verwoerd T.C., Krutwagen R.W.H.H., Goddijn O.J.M. (1998) Trehalose-producing transgenic tobacco plants show improved growth performance under drought stress, J. Plant Physiol. 152, 525 – 532. 41. Premachandra G.S., Saneoka H., Kanaya M., Ogata S. (1991) Cell membrane stability and leaf surface wax content as affected by increasing water deficits in maize, J. Exp. Bot. 42, 167 – 171. 42. Prochazkova D.,

Sairam R.K., Srivastava G.C., Singh D.V. (2001) Oxidative stress and antioxidant activity as the basis of senescence in maize leaves, Plant Sci. 161, 765 – 771. 43. Quan R.D., Shang M., Zhang H., Zhang J. (2004) Improved chilling tolerance by transformation with bet A gene for the enhancement of glycinebetaine synthesis in maize, Plant Sci. 166, 141 – 149. 44. Ramon M., Rollan F., Thevelein J., Dijck P., Leyman B. (2007) ABI4 mediates the effects of exogenous trehalose on Arabidopsis growth and starch breakdown, Plant Mol. Biol. 63, 195 – 206. 45. Ratnayaka H.H., Molin W.T., Sterling T.M.

(2003) Physiological and antioxidant responses of cotton and spurred anoda under interference and mild drought, J. Exp. Bot. 54, 2293 – 2305. 46. Reynolds M.P., Oritz-Monasterio J.I., Mc Nab A. (2001) Application of physiology in wheat breeding, CIMMYT, Mexico. 47. Riccardi L., Polignano G.B., de Giovanni C. (2001) Genotypic response of faba bean to water stress, Euphytica 118, 39 – 46. 48. Sairam R.K., Deshmukh P.S., Saxena D.C. (1998) Role of antioxidant systems in wheat genotypes tolerance to water stress, Biol. Plant. 41, 387 – 394. 49. Sakamoto A., Murata N.

(2002) the role of glycinebetaine in the protection of plants from stress: clues from transgenic plants, Plant Cell Environ. 25, 163 – 171. 50. Liu J.H., Kitashiba H., Wang J., Ban Y., Moriguch T. (2007) Polyamines and their ability to provide environmental stress tolerance to plants, Plant Biotechnol. 24, 117 – 126. 51. Shelp B.L., Bown A.W.,McLean M.D. (1999) Metabolism and functions ogamma aminobutyric acid, Trends Plant Sci. 11, 446 – 452. 52. Kinnersley A.M., Turano F.J. (2000) Gama aminobutyric acid (GABA) and plant responses to stress, Crit. Rev. Plant Sci. 19, 479 – 509. 53. Wahid A., Gelani S., Ashraf M., Foolad M.R. (2007) Heat tolerance in plants: an overview, Environ. Exp. Bot.

61, 199 – 223. 54. Simon-sarkadi, L., Kocsy G., Várhegyi Á., Galiba G., De Ronde J.A. 2006. Stress-induced changes in the free amino acid composition in transgenic soybean plants having increased proline content, Biol.Plant. 50, 793 – 796. 55. Goddijn O.J.M., Verwoerd T.C., Voogd E., Krutwagen P.W.H.H., Degraaf P.T.H.M., Poels J., Vandun K., Ponstein A.S.,

Damm B., Pen J. (1997) Inhibition of trehalase activity enhances trehalose accumulation in transgenic plants, Plant Physiol. 113, 181 190. 56. Wingler A. (2002) The function of trehalose biosynthesis in plants, Phytochemistry 60, 437 – 440. 57. Penna S. (2003) Building stress tolerance through overproducing trehalose in transgenic plants, Trends Plant Sci. 8, 355 – 357. 58. Kosmas S.A.,

Argyrokastritis A., Loukas M.G., Eliopoulos E., Tsakas S., Kaltsikes P.J. (2006) Isolation and characterization of drought related trehalose 6-phosphate-synthase gene from cultivated cotton (Gossypium hirsutum L.), Planta 223, 329 – 339. 59. Lee S.B., Kwon H.B., Kwon S.J., Park S.C., Jeong M.J., Han S.E., Byun M.O., Daniell H. (2004) Accumulation of trehalose within transgenic chloroplasts confers drought tolerance, Mol. Breed. 11, 1 – 13. 60. Karim S., Aronsson H., Ericson H., Pirhonen M., Leyman B., Welin B.,Mäntylä E., Palva E.T., Dijck P.V., Holmström K. (2007). Improved drought tolerance without undesired side effects in transgenic plants producing trehalose, Plant Mol. Biol. 64, 371 – 386. 61. Zhu J.K.

(2002) Salt and drought stress signal transduction in plants, Annu. Rev. Plant Biol. 53, 247 – 273. 62. Ashraf M., Foolad M.R. (2007) Roles of glycinebetaine and proline in improving plant abiotic stress resistance, Environ. Exp. Bot. 59, 206 – 216. 63. Naidu B.P., Cameron D.F., Konduri S.V. (1998) Improving drought tolerance of cotton by glycinebetaine application and selection, in: Proceedings of the 9th Australian agronomy conference, Wagga Wagga. 64. Chen W.P., Li P.H., Chen T.H.H. (2000) Glycinebetaine increases chilling tolerance and reduces chilling-induced lipid peroxidation in Zea mays L., Plant Cell Environ. 23, 609 618. 65. Hussain M., Malik M.A., Farooq M., Ashraf M.Y., Cheema M.A.

(2008) Improving Drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower, J. Agron. Crop Sci. 194, 193 – 199. 66. Subbarao G.V., Nam N.H., Chauhan Y.S., Johansen C. (2000) Osmotic adjustment, water relations and carbohydrate remobilization in pigeon pea under water deficits, J. Plant Physiol. 157, 651 – 659. 67. Azam F., Ashraf M., Ashraf M.Y., Iqbal N. (2005) Effect of exogenous application of glycinebetaine on capitulum size and achene number of sunflower under water stress, Int. J. Biol. Biotechnol. 2, 765 – 771. 68. Ma Y.Z.

(2007) GmDREB2, a soybean DRE-binding transcription factor, conferred drought and high-salt tolerance in transgenic plants, Biochem. Bioph. Res. Co. 353, 299 – 305. 69. Kubi´s J. (2003) Polyamines and "scavenging system": influence of exogenous spermidine on catalase and guaiacol peroxidase activities, and free polyamine level in barley leaves under water deficit, Acta Physiol. Plant. 25, 337 – 343. 70. Yang J., Zhang J., Liu K., Wang Z., Liu L. (2007) Involvement of polyamines in the drought resistance of rice,

J. Exp. Bot. 58, 1545 – 1555. 71. Ayensu, ES. 1996. World Medicinal Plant Resources. Pp. 11-42 in Conservation for Productive Agriculture.

(VL Chopra and TN Khoshoo, eds). ICAR, New Delhi, India. Boorsma, WG. 1926. Notes about eastern medicine in Java, Botanical Garden, Bogor, Indonesia. 72. Salleh, MK, S Natesh, A Osman and AA Kadir (eds). 1997. Medicinal and aromatic plants: Strategies and technologies for conservation. Proceedings of the Symposium State-ofthe- Art Strategies and Technologies for Conservation of Medicinal and Aromatic 73. Plants. Kuala Lumpur, Malaysia, 29-30 September 1997. Ministry of Science, Technology and Environment, Malaysia and Forest Research Institute, Malaysia. 74. Kumar, S, SA Hassan, S Dwivedi, AK Kukreja, A Sharma, AK Singh, S Sharma and R Tewari (eds). 2000.

Proceedings of the National Seminar on the Frontiers of Research and Development in Medicinal Plants,16-18 September 2000. Journal Medicinal and Aromatic Plant Sciences Vol. 22/4A and Vol. 23/1A. Central Institute of Medicinal and Aromatic Plants (CIMAP). Lucknow, India. 75. Natesh, S. 2000. Biotechnology in the conservation of medicinal and aromatic plants. Pp. 548- 561 in Biotechnology in Horticulture and Plantation Crops. KL Chadha, PN Ravindran and Leela Sahajram (eds), Malhotra Publishing House, New Delhi, India. 76. Chadha, KL and R Gupta (eds). 1995. Advances in Horticulture: Medicinal and Aromatic Plants Vol. 11. Malhotra Publishing House, New Delhi, India.

Chandel KPS, G Shukla and N Sharma. 1996. Biodiversity in Medicinal and Aromatic Plants in India. National Bureau of Plant Genetic Resources, New Delhi, India. 77. Paisooksantivatana, Y., S Kako and H Seko. 2001. Isozyme polymorphism in Curcuma alismatifolia Gagnep. (Zingiberaceae) populations from Thailand. Scientia Horticulturae 88(4): 299-307. 78. Sharma, KD, BM Singh, TR Sharma, M Katoch and S Guleria. 2000. Molecular analysis of variability in Podophyllum hexandrum Royle - An endangered medicinal herb of northwestern Himalaya. Plant Genetic Resources Newsletter (FAO/IPGRI) 124: 57-61. 79. Rajasekharan, PE and S Ganeshan.

2002 Conservation of medicinal plant biodiversity in Indian perspective. Journal of Medicinal and Aromatic Plant Sciences 24(1): 132-147. 80. Hamid, A and D Sitepu. 1990. An understanding of native herbal medicine in Indonesia. Industrial Crops Research Journal 3(1): 11-17. 81. Latif, A. 1997. Medicinal and aromatic plants of Asia: Approaches to exploitation and conservation. Pp. 20-31 in Medicinal and Aromatic Plants. Strategies and Technologies for Conservation. Proceedings of the Symposium State-of-the-Art Strategies and Technologies for Conservation of Medicinal and Aromatic Plants. Kuala Lumpur, Malaysia, 29-30 September 1997.

Ministry of Science, Technology and Environment, and the Malaysia and Forest Research

Institute, Malaysia. 82. Samant, SS, U Dhar and LMS Palni. 1998. Medicinal Plants of Indian Himalayas: Diversity, Distribution, Potential values. Himavikas Publication No. 13, G.B. Pant Institute of Himalayan Environment and Development, Almora, Uttaranchal, India. 83. Somerville C., Briscoe J. (2001) Genetic engineering and water, Science . 292, 2217. 84. Zhou Y., Lam H.M., Zhang J. (2007) Inhibition of photosynthesis and energy dissipation induced by water and high light stresses in rice, J. Exp. Bot. 58, 1207 – 1217. 85. Sajedi, N. and Sajedi. AS.,

2008, Effect of drought stress on physiological characteristics of maize mycorrhiza and zinc. Journal of Crop Science. Volume 11, No. 3, p. 202 to 222. 86. Taheri AM, Daneshian J, Valadabadi SAR, Aliabadi FH (2008). Effects of water deficit and plant density on morphological characteristics of chicory (Cichorium intybus L.). Abstracts Book of 5thInternational Crop Science Congress & Exhibition p.26. 87. Mazzafera P, Teixeira JPF (2006). Proline in coffee subjected to drought stress. Turrialba. Universidade Estadual de Campinas, IB, Departament to de Fisiologia Vegetal, CP 6109, Campinas, SP, CEP 13081, Brazil. 88. Munne-Bosch S., Penuelas J.

(2003) Photo and antioxidative protection, and a role for salicylic acid during drought and recovery in field grown Phillyrea angustifolia plants, Planta 217, 758 – 766. 89. Foyer C.H., Fletcher J.M. (2001) Plant antioxidants: colour me healthy, Biologist 48, 115 – 120. 90. Niyogi K.K. (1999) Photo protection revisited: genetic and molecular approaches, Annu. Rev. Plant Phys. 50, 333 – 359. 91. Reddy A.R., Chaitanya K.V., Vivekanandan M. (2004) Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants, J. Plant Physiol. 161, 1189 – 1202. 92. Fazeli F., Ghorbanli M., Niknam V.

(2007), Effect of drought on biomass, protein content, lipid peroxidation and antioxidant enzymes in two sesame cultivars, Biol. Plant. 51, 98 – 103. 93. Apel K., Hirt H. (2004) Reactive oxygen species: metabolism, oxidative stress, and signal transduction, Annu. Rev. Plant Biol. 55, 373 – 99. 94. Lamb C., Dixon R.A. (1997) The oxidative burst in plant disease resistance, Annu. Rev. Plant Phys. 48, 251 – 275. 95. Sairam R.K., Srivastava G.C., Agarwal S., Meena R.C. (2005) Differences in antioxidant activity in response to salinity stress in tolerant and susceptible wheat genotypes, Biol. Plant. 49, 85 – 91. 96. Gille L., Nohl H.

(2001) The ubiquinol/bc1 redox couple regulates mitochondrial oxygen radical formation, Arch. Biochem. Biophys. 388, 34 – 38. 97. Blokhina O., Virolainen E., Fagerstedt K.V. (2003) Antioxidants, oxidative damage and oxygen deprivation stress: a review, Ann. Bot. 91, 179 – 194. 98. Beck E.H., Fettig S., Knake C., Hartig K., Bhattarai T. (2007) Specific and unspecific responses of plants to cold and drought stress, J. Biosci. 32, 501 – 510. 99. Chaves M.M., Oliveira M.M. (2004) Mechanisms underlying plant

resilience to water deficits: prospects for water-saving agriculture, J. Exp. Bot. 55, 2365 – 2384. 100. Araus J.L., Slafer G.A., Reynolds M.P., Royo C.

(2002) Plant breeding and drought in C3 cereals: what should we breed for? Ann. Bot. 89,925 – 940. 101. Siddique K.H.M., Loss S.P., Thomson B.D. (2003) Cool season grain legumes in dry land Mediterranean environments of Western Australia: Significance of early flowering, in: Saxena N.P. (Ed.), Management of Agricultural Drought. Science Publishers, Enfield (NH), USA, pp. 151 – 161. 102. DaMatta F.M. (2004) Exploring drought tolerance in coffee: a physiological approach with some insights for plant breeding, Braz. J. Plant Physiol. 16, 1 – 6. 103. Kumar J., Abbo S.

(2001) Genetics of flowering time in chickpea and its bearing on productivity in the semi-arid environments, Adv. Agron. 72, 107 – 138. 104. Turner N.C., Wright G.C., Siddique K.H.M. (2001) Adaptation of grain legumes (pulses) to water-limited environments, Adv. Agron. 71, 123 – 231. 105. Kavar T., Maras M., Kidric M., Sustar-Vozlic J., Meglic V. (2007) Identification of genes involved in the response of leaves of Phaseolus vulgaris to drought stress, Mol. Breed. 21, 159 – 172. 106. Subbarao G.V., Johansen C., Slinkard A.E., Rao R.C.N. , Saxena N.P., Chauhan Y.S.

(1995) Strategies and scope for improving drought resistance in grain legumes, Crit. Rev. Plant Sci. 14, 469 – 523. 107. Ludlow MM, Muchow RC (1990). A critical evaluation of the traits for improving crop yield in water limited environments. Adv. Agron. 43:107 – 153. 108. Richards R.A., Rawson H.M., Johnson D.A. (1986) Glaucousness in wheat: its development, and effect on water-use efficiency, gas exchange and photosynthetic tissue temperatures, Aust. J. Plant Physiol. 13, 465 – 473. 109. Schuppler U., He P.H., John P.C.L., Munns R. (1998) Effects of water stress on cell division and cell-division-cycle-2-like cell-cycle kinase activity in wheat leaves, Plant Physiol. 117, 667 – 678. 110. Sandquist D.R., Ehleringer J.R.

(2003) Population- and family-level variation of brittlebush (Encelia farinosa, Asteraceae) pubescence: its relation to drought and implications for selection in variable environments, Am. J. Bot. 90, 1481 – 1486. 111. Nerd A., Neumann P.M. (2004) Phloem water transport maintains stem growth in a drought- stressed crop cactus (Hylocereus undatus), J. Am. Soc. Hortic. Sci. 129, 486 – 490. 112. Nguyen H.T., Babu R.C., Blum A. (1997) Breeding for drought resistance in rice: Physilogy and molecular genetics considerations, Crop Sci. 37, 1426 – 1434. 113. Upreti K.K., Murti G.S.R., Bhatt R.M.

(2000) Response of pea cultivars to water stress: changes in morpho-physiological characters, endogenous hormones and yield, Veg. Sci. 27, 57 – 61. 114. Pannu R.K., Singh D.P., Singh P., Chaudhary B.D., Singh V.P. (1993) Evaluation of various plant water indices

for screening the genotypes of chickpea under limited water environment, Haryana J. Agron. 9, 16 – 22. 115. Kramer PJ, Boyer JS (1995). Water Relations of Plants and Soils. Academic press, San Diego, USA pp: 1-495. Kucharski WA, Mordaiski R (2008). The compasion of efficiency of tillage coriander in conventional and ecological system. J. Res. Appl. Agric. Eng. 53(3): 152-155. 116. Yokota A., Kawasaki S., Iwano M.,

Nakamura C., Miyake C., Akashi K. (2002) Citrulline and DRIP-1 Protein (ArgE Homologue) in Drought Tolerance of Wild Watermelon, Ann. Bot. 89, 825 – 832. 117. Morgan P.W. (1990) Effects of abiotic stresses on plant hormone systems, in: Stress Responses in plants: adaptation and acclimation mechanisms, Wiley-Liss, Inc., pp. 113 – 146. 118. Taiz L., Zeiger E. (2006) Plant Physiology, 4th Ed., Sinauer Associates Inc. Publishers, Massachusetts. 119. Gong H., Zhu X., Chen K., Wang S., Zhang C. (2005) Silicon alleviates oxidative damage of wheat plants in pots under drought, Plant Sci. 169, 313 – 321. 120. Hasegawa P.M., Bressan R.A., Zhu J.K., Bohnert H.J.

(2000) Plant cellular and molecular responses to high salinity, Annu. Rev. Plant Phys. 51, 463 – 499. 121. Farooq M., Aziz T., Basra S.M.A., Cheema M.A., Rehamn H. (2008) Chilling tolerance in hybrid maize induced by seed priming with salicylic acid, J. Agron. Crop Sci. 194, 161 – 168. 122. Jimenez A., Hernandez J.A., Ros Barcelo A., Sandalio L.M., del Rio L.A., Sevilla F. (1998) Mitochondrial and peroxisomal ascorbate peroxidase of pea leaves, Physiol. Plant. 104, 687 – 692. 123. Orvar B.L., Ellis B.E.

(1997) Transgenic tobacco plants expressing antisense RNA for cytosolic ascorbate peroxidase show increased susceptibility to ozone injury, Plant J. 11, 1297 – 1305. 124. Pastori G., Foyer C.H., Mullineaux P. (2000) Low temperature-induced changes in the distribution of H_2O_2 and antioxidants between the bundle sheath and mesophyll cells of maize leaves, J. Exp. Bot. 51, 107 – 113. 125. Stevens R.G., Creissen G.P., Mullineaux P.M. (2000) Characterization of pea cytosolic glutathione reductase expressed in transgenic tobacco, Planta 211, 537 – 545. 126. Chew O., Whelan J., Miller A.H.

(2003) Molecular definition of the ascorbate-glutathione cycle in Arabidopsis mitochondria reveals dual targeting of antioxidant defences in plants, J. Biol. Chem. 278, 46869 – 46877. 127. Lima A.L.S., DaMatta F.M., Pinheiro H.A., Totola M.R., Loureiro M.E. (2002) Photochemical responses and oxidative stress in two clones of Coffea canephora under water deficit conditions, Environ. Exp. Bot. 47, 239 – 247. 128. Pinheiro H.A., DaMatta F.M., Chaves A.R.M., Fontes E.P.B., Loureiro M.E. (2004) Drought tolerance in relation to protection against oxidative stress in clones of Coffea canephora subjected to long-term drought, Plant Sci. 167, 1307 – 1314. 129. Pan Y., Wu L.J., Yu Z.L.

(2006) Effect of salt and drought stress on antioxidant enzymes activities and SOD

isoenzymes of liquorice (Glycyrrhiza uralensis Fisch), Plant Growth Regul. 49, 157 – 165. 130. Havaux M. (1998) Carotenoids as membrane stabilizers in chloroplasts, Trends in Plant Sci. 3, 147 – 151. 131. Wahid A. (2007) Physiological implications of metabolites biosynthesis in net assimilation and heat stress tolerance of sugarcane (Saccharum officinarum) sprouts, J. Plant Res. 120, 219 – 228. 132. Wahid A., Close T.J.

(2007) Expression of dehydrins under heat stress and their relationship with water relations of sugarcane leaves, Biol. Plantarum 51, 104 – 109. 133. Bajji M., Kinet J., Lutts S. (2002). The use of the electrolyte leakage method for assessing cell membrane stability as a water stress tolerance test in durum wheat, Plant Growth Regul. 36, 61 – 70. 134. Dhanda S.S., Sethi G.S., Behl, R.K. (2004) Indices of drought tolerance in wheat genotypes at early stages of plant growth, J. Agron. Crop Sci. 190, 6 – 12. 135. Wang Z., Huang B. (2004) Physiological Recovery of Kentucky bluegrass from simultaneous drought and heat stress, Crop Sci.

44, 1729 – 1736. 136. Villar-Salvador P., Planelles R., Oliet J., Penuelas-Rubira J.L., Jacobs D.F., González M. (2004) Drought tolerance and transplanting performance of holm oak (Quercus ilex) seedlings after drought hardening in the nursery, Tree Physiol. 24, 1147 – 1155. 137. Folkert A.H., Elena A.G., Buitink J. (2001) Mechanisms of plant desiccation tolerance, Trends Plant Sci. 6, 431 – 438. 138. Gigon A., Matos A., Laffray D., Zuily-fodil Y., Pham-Thi A. (2004) Effect of drought stress on lipid metabolism in the leaves of Arabidopsis thaliana (Ecotype Columbia), Ann. Bot. 94, 345 – 351. 139. Serraj R., Sinclair T.R.

(2002) Osmolyte accumulation: can it really help increase crop yield under drought conditions? Plant Cell Environ. 25, 333 – 341. 140. SRBary .SST.R. Aatiof - aminobutyric acid in nodulated soybean in response to drought stress, Physiol. Plant. 102, 79 – 86. 141. Moinuddin K.H.M., Khannu-Chopra R. (2004) Osmotic adjustment in chickpea in relation to seed yield and yield parameters, Crop Sci. 44, 449 – 455. 142. Alexieva V., Sergiev I., Mapelli S., Karanov E. (2001) the effect of drought and ultraviolet radiation on growth and stress markers in pea and wheat, Plant Cell Environ. 24, 1337 – 1344. 143. Kawasaki S., Miyake C., Kouchi T., Yokota A.

(2000) Responses of wild watermelon to drought stress: accumulation of an ArgE homologue and citrulline in leaves during water deficit, Plant Cell Phys. 41, 864 – 873. 144. Akashi K., Miyake C., Yokota A. (2001) Citrulline, a novel compatible solute in drought- tolerant wild watermelon leaves, is an efficient hydroxyl radical scavenger, FEBS Lett. 508, 438 – 442. 145. Bektasoglu B., Esin C.S, Ozyürek Mustafa O., Kubilay G., Resat A. (2006) Novel hydroxyl radical scavenging antioxidant activity assay for water-soluble antioxidants using a modified CUPRAC method, Biochem. Bioph. Res. Co.

345, 1194 – 2000.

INTERNET SOURCES:

2% -
http://internationalscholarsjournals.org/download.php?id=529146419394795113.pdf&type=application/pdf&op=1
2% -
https://www.researchgate.net/profile/Alex_Katava/publication/237228545_Medicinal_and_aromatic_plants_farming_under_drought_conditions/links/0c96053b2f656df5c8000000.pdf
<1% - http://www.aensiweb.net/AENSIWEB/aejsa/aejsa/2009/53-56.pdf
<1% -
https://www.researchgate.net/publication/325497635_EFFECTS_OF_DROUGHT_STRESS_AND_FIELD_TREATMENTS_ON_SEED_GERMINATION_AND_EARLY_GROWTH_TRAITS_OF_PARENTAL_BERSEEM_CLOVER_SEEDS
2% -
https://www.researchgate.net/profile/Davood_Barari/publication/294108106_Effect_of_Drought_Stress_and_its_Mechanism_in_Plants/links/5bc3a66e299bf1004c5f3bc2/Effect-of-Drought-Stress-and-its-Mechanism-in-Plants.pdf
<1% -
https://www.researchgate.net/publication/224837225_Strategies_for_Conservation_and_utilization_of_Medicinal_Plant_Genetic_Resources
<1% - https://extension2.missouri.edu/mp902
1% -
http://intranet.tdmu.edu.ua/data/kafedra/internal/pharma_1/classes_stud/en/pharm/prov_pharm/ptn/Resouces/5%20-%20course/%E2%84%9601_Subject%20and%20task%20of%20resources%20of%20medicinal%20plants.htm
<1% - https://academicjournals.org/journal/AJMR/article-full-text-pdf/A85FB1854678
3% - https://www.scribd.com/doc/19016091/Herbal
<1% - http://www.himalayanvoices.org/?q=onlinelib/research/eco&page=1
<1% - http://www.scialert.net/fulltext/?doi=rjmp.2011.685.694
<1% -
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.367.9038&rep=rep1&type=pdf
<1% -
http://www.bashanfoundation.org/contributions/Khalvati-M/2009.-Khalvati-AJAS.pdf
1% - http://ijcrar.com/6-9-2018/Kedir%20Wulchafo%20Hussen2.pdf

<1% - https://www.sciencedirect.com/science/article/pii/S0378377417300902

1% - https://www.researchgate.net/publication/294108106_Effect_of_Drought_Stress_and_its_Mechanism_in_Plants

<1% - http://jmpb.areeo.ac.ir/article_108496_ca7575a9235c1fbc4a8028b39022e3eb.pdf

<1% - https://www.thefreelibrary.com/Effect+of+drought+stress+on+qualitative+and+quantitative...-a0267421951

<1% - https://www.researchgate.net/publication/297271755_Effect_of_drought_stress_on_leaf_and_whole_canopy_radiation_use_efficiency_and_yield_of_maize

<1% - https://mtmeru.com/incense-essential-oil/index.html

<1% - https://www.essentialoilssupplies.com/

<1% - http://www.academicjournals.org/app/webroot/article/article1381409529_Abbaszadeh%20et%20al.pdf

<1% - https://www.researchgate.net/publication/237228545_Medicinal_and_aromatic_plants_farming_under_drought_conditions

<1% - http://www.ipcbee.com/vol1/88-B40002.pdf

<1% - https://www.researchgate.net/publication/26551760_Influence_of_water_stress_on_growth_essential_oil_and_chemical_composition_of_herbs_Ocimum_sp

<1% - https://www.researchgate.net/publication/229590679_Effect_of_drought_stress_on_growth_and_essential_oil_metabolism_in_lemongrasses

<1% - http://www.academicjournals.org/app/webroot/article/article1379425705_Ebrahimi%20et%20al.pdf

<1% - https://portal.nifa.usda.gov/web/crisprojectpages/0411505-managing-limited-irrigation-and-rainfall-for-crop-production-in-semi-arid-environments.html

<1% - https://www.researchgate.net/publication/269048302_Improving_irrigation_practice_in_New_Zealand

<1% - https://pdfs.semanticscholar.org/6e02/3cf6f254f95dcd8b45726b9a26443afad148.pdf

<1% - http://europepmc.org/articles/PMC5666749

<1% - https://hort.purdue.edu/rhodcv/hort640c/PROLINE/pr00002.htm

<1% - https://hort.purdue.edu/rhodcv/hort640c/PROLINE/pr00005.htm

<1% - http://www.hort.purdue.edu/rhodcv/hort640c/PROLINE/pr00002.htm

<1% - https://www.academia.edu/1093288/Growth_water_content_and_proline_accumulation_in_drought-stressed_callus_of_date_palm

<1% - https://www.researchgate.net/publication/226210079_Effects_of_Short-term_Red_Radiation_and_Choline_Compounds_on_Cytokinin_Content_Chlorophyll_Accumulation_and_Photomorphogenesis_in_Wheat_Seedlings

<1% - https://www.researchgate.net/publication/225124709_Photosynthesis_of_Rehmannia_glutinosa_subjected_to_drought_stress_is_enhanced_by_choline_chloride_through_alleviating_lipid_peroxidation_and_increasing_proline_accumulation

<1% - https://www.researchgate.net/publication/255482435_The_effect_of_water_deficit_and_excess_copper_on_proline_metabolism_in_Nicotiana_benthamiana

<1% - https://www.researchgate.net/publication/11939509_Plant_antioxidants_Colour_me_healthy

1% - https://www.researchgate.net/publication/257828589_Plant_Drought_Stress_Effects_Mechanisms_and_Management

3% - https://www.scribd.com/document/254441628/Drought-Stress-Effects-Mechanism

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4657901/

<1% - https://www.sciencedirect.com/science/article/pii/S0378377418308138

<1% - https://www.researchgate.net/publication/223502591_Physiological_and_molecular_responses_of_Aeluropus_lagopoides_Poaceae_to_water_deficit

<1% - http://www.authorstream.com/Presentation/kkcr-1626731-breeding-wheat-drought-tolerance-mechanism-kkc/

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3578903/

<1% - http://www.esalq.usp.br/lepse/imgs/conteudo_thumb/Antioxidants-oxidative-damage-and-oxygen-depravation-stress---a-review.pdf

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4244988/

<1% - https://www.researchgate.net/publication/236623883_Legume-rhizobia_symbiotic_interaction_under_salt_and_drought_constraints_Generation_of_reactive_oxygen_species_and_protective_role_of_antioxidant_enzymes_within_nodules

<1% - https://academic.oup.com/aob/article/91/2/179/131136

<1% - https://www.researchgate.net/publication/328415100_Ascorbate-Glutathione_and_Plant_Tolerance_to_Various_Abiotic_Stresses

<1% - https://www.researchgate.net/publication/281650354_Effects_of_water_deficit_on_plant_growth_water_relations_and_photosynthesis

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3063356/

<1% - http://www.uaiasi.ro/CERCET_AGROMOLD/CA4-11-02.pdf

4% - https://www.ijcmas.com/6-4-2017/Omprakash,%20et%20al.pdf

2% - https://www.slideshare.net/8179360367/plant-drought-effects-mechanisms-and-management

<1% - https://www.researchgate.net/publication/226367286_Phenological_responses_of_Oryza_sativa_O_glaberrima_and_inter-specific_rice_cultivars_on_a_toposquence_in_West_Africa

<1% - https://www.researchgate.net/publication/227045181_Identification_of_genes_involved_in_the_response_of_leaves_of_Phaseolus_vulgaris_to_drought_stress

<1% - https://www.slideshare.net/VelentinaDas/project-report-submitted-to-the-compatible

<1% - https://www.researchgate.net/publication/51206606_Population-_and_family-level_variation_of_brittlebush_Encelia_farinosa_Asteraceae_pubescence_Its_relation_to_drought_and__implications_for_selection_in_variable_environments

<1% - https://www.researchgate.net/publication/242107568_Phloem_Water_Transport_Maintains_Stem_Growth_in_a_Drought-stressed_Crop_Cactus_Hylocereus_undatus

<1% - https://lupinepublishers.com/agriculture-journal/pdf/CIACR.MS.ID.000246.pdf

1% - https://www.researchgate.net/publication/226466203_Genotypic_response_of_faba_bean_to_water_stress

<1% - https://www.sciencedirect.com/science/article/pii/S0098847210001875

<1% - https://www.jstor.org/stable/42795974

<1% - https://www.researchgate.net/publication/11273376_Citrulline_and_DRIP1_Protein_ArgE_Homologue_in_Drought_Tolerance_of_Wild_Watermelon

<1% - https://academic.oup.com/aob/article/89/7/825/150795

1% - http://www.kspbtjpb.org/journal/view.html?doi=10.5010/JPB.2019.46.4.331

<1% - https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-3040.1992.tb01457.x

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6978204/

<1% - https://www.sciencedirect.com/science/article/pii/S0166445X19301523

<1% - https://www.intechopen.com/books/plant-growth/molecular-and-morphophysiological-analysis-of-drought-stress-in-plants

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2803587/

<1% - http://www.textroad.com/pdf/JAEBS/J.%20Appl.%20Environ.%20Biol.%20Sci.,%205(8)161-165,%202015.pdf

1% - https://www.researchgate.net/publication/229645378_Transgenic_tobacco_plants_expressing_antisense_RNA_for_cytosolic_ascorbate_peroxidase_show_increased_susceptibility_to_ozone_injury

<1% - https://www.hindawi.com/journals/jb/2012/217037/

<1% - https://www.researchgate.net/publication/261706758_Drought_tolerance_in_relation_to_protection_against_oxidative_stress_in_clones_of_Coffea_canephora_subjected_to_long-term_drought

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2707349/

<1% - https://www.sciencedirect.com/science/article/pii/S0927776507003876

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5217938/

<1% - https://www.researchgate.net/publication/291954185_Effect_of_Silicon_on_Photosynthetic_Gas_Exchange_Photosynthetic_Pigments_Cell_Membrane_Stability_and_Relative_Water_Content_of_Different_Wheat_Cultivars_under_Drought_Stress_Conditions

<1% - https://www.researchgate.net/publication/226524003_QTLs_for_cell-membrane_stability_mapped_in_rice_Oryza_sativa_L_under_drought_stress

<1% - https://www.researchgate.net/publication/229665494_Indices_of_Drought_Tolerance_in_Wheat_Genotypes_at_Early_Stages_of_Plant_Growth

<1% - https://www.sciencedirect.com/science/article/pii/B9780128029220000054

<1% - https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0037344

<1% - https://www.researchgate.net/publication/8415494_Drought_tolerance_and_transplanting_performance_of_holm_oak_Quercus_ilex_seedlings_after_drought_hardening_in_the_nursery

<1% - https://www.sciencedirect.com/science/article/pii/S1360138501020520

<1% - https://www.sciencedirect.com/science/article/pii/S0378429012002080

<1% - https://www.researchgate.net/publication/8433021_Effect_of_Drought_Stress_on_Lipid_

<1% - https://www.researchgate.net/publication/6762763_ABI4_mediates_the_effects_of_exogenous_trehalose_on_Arabidopsis_growth_and_starch_breakdown

<1% - https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/gigaspora-margarita

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6862505/

<1% - https://www.sciencedirect.com/science/article/pii/S0098847206000268

<1% - https://journals.ashs.org/hortsci/abstract/journals/hortsci/53/12/article-p1842.xml

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2267253/

<1% - https://www.researchgate.net/publication/229988236_Effects_of_exogenous_glycinebetaine_on_growth_CO2_assimilation_and_photosystem_II_photochemistry_of_maize_plants

<1% - https://www.researchgate.net/publication/229785682_Physiological_Role_of_Exogenously_Applied_Glycinebetaine_to_Improve_Drought_Tolerance_in_Fine_Grain_Aromatic_Rice_Oryza_sativa_L

<1% - https://mafiadoc.com/salicylic-acid_5aa2fe8c1723ddbb0c906570.html

<1% - https://www.researchgate.net/publication/228891865_Does_seed_treatment_with_glycinebetaine_improve_germination_rate_and_seedling_growth_of_sunflower_Helianthus_annuus_L_under_osmotic_stress

<1% - https://www.researchgate.net/publication/226131788_Glycinebetaine_application_ameliorates_negative_effects_of_drought_stress_in_tobacco

<1% - https://www.sciencedirect.com/science/article/pii/S0031942210003031

<1% - https://www.researchgate.net/publication/271928787_Change_in_Free_Polyamine_Contents_and_Expression_Profiles_of_Two_Polyamine_Biosynthetic_Genes_in_Citrus_Embryogenic_Callus_under_Abiotic_Stresses

<1% - https://mafiadoc.com/oxidative-stress-in-plants-causes-consequences-and-_5aa2f5af1723ddbc0cb6bc2e.html

2% - https://link.springer.com/chapter/10.1007/978-1-4614-5001-6_5

<1% - http://journals.areo.ir/article_109415.html

<1% - http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8137.1996.tb04508.x/abstract

<1% - https://wenku.baidu.com/view/faf0fbf9c8d376eeaeaa31cc.html

<1% - http://www.crida.in/Pubs/Abiotic_Stress_in_Plants_-_Mechanisms_and_Adaptations_2011

.pdf

<1% - https://link.springer.com/chapter/10.1007%2F978-981-32-9151-5_25

<1% - https://www.researchgate.net/publication/11316470_Effect_of_Drought_Stress_on_the_Yield_and_Composition_of_Volatile_Oils_of_Drought-Tolerant_and_Non-Drought-Tolerant_Clones_of_Tagetes_minuta

<1% - https://www.researchgate.net/publication/317543728_WATER_DEFICIT_INDUCED_PHYSIOLOGICAL_AND_YIELD_RESPONSES_IN_ORYZA_SATIVA_L

<1% - https://www.science.gov/topicpages/s/salt+stress+induced

<1% - http://europepmc.org/articles/PMC3550502

<1% - https://epdf.pub/abiotic-stress-responses-in-plants-metabolism-productivity-and-sustainability.html

4% - https://link.springer.com/chapter/10.1007%2F978-90-481-2666-8_12

<1% - https://www.jstage.jst.go.jp/article/ecb1963/41/1/41_1_3/_article/references/-char/ja/

<1% - https://www.sciencedirect.com/science/article/pii/S2095311919626031

<1% - https://link.springer.com/chapter/10.1007%2F978-3-030-06118-0_16

<1% - https://wenku.baidu.com/view/33b716cd3b3567ec112d8a8a.html

<1% - https://link.springer.com/chapter/10.1007%2F978-3-319-32423-4_1

<1% - https://link.springer.com/article/10.1007/s11703-008-0009-3

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4158992/

<1% - https://link.springer.com/chapter/10.1007%2F978-81-322-2616-1_5

<1% - https://link.springer.com/chapter/10.1007/978-3-319-13368-3_10

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5902779/

<1% - https://link.springer.com/chapter/10.1007/978-3-642-32653-0_1

<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4183588/

<1% - http://cgs.unisel.edu.my/v3/wp-content/uploads/2016/08/Aziah-Mohd-Yusoff-Dr.pdf

<1% - https://it.linkedin.com/in/musse-tesfaye

<1% - https://www.researchgate.net/publication/285403796_Antimicrobial_activity_of_Ixora_alba_Plumeria_obtusa_and_Psidium_guajava

<1% - https://mafiadoc.com/promoting-rhizobacteria-pgpr-and-medicinal-plants_5a7574e81723dd4bf41c85b3.html

<1% - https://www.tandfonline.com/doi/full/10.1080/17451590903230249

<1% - https://issuu.com/abdurrahmansetyawan/docs/n050100aaall

<1% - https://link.springer.com/article/10.1007/s12298-012-0105-y

<1% - https://link.springer.com/chapter/10.1007/978-1-4614-0634-1_7
<1% - https://link.springer.com/article/10.1007/s10725-013-9881-9
<1% - https://link.springer.com/chapter/10.1007/978-3-642-10305-6_7
<1% - http://www.hort.purdue.edu/rhodcv/hort640c/referen/metnet.htm
<1% - https://link.springer.com/article/10.1007%2Fs10681-006-4261-4
<1% - https://link.springer.com/article/10.1007/s10528-013-9571-3
<1% - https://link.springer.com/chapter/10.1007/978-3-642-32653-0_7
<1% - https://link.springer.com/chapter/10.1007%2F978-3-030-23400-3_12
<1% - https://link.springer.com/chapter/10.1007/978-90-481-3709-1_18
<1% - https://link.springer.com/chapter/10.1007/978-3-319-32423-4_17
<1% -
http://www.kspbtjpb.org/journal/download_pdf.php?doi=10.5010/JPB.2019.46.4.331
<1% -
https://www.researchgate.net/publication/311990133_Glycinebetaine-Mediated_Abiotic_
Oxidative-Stress_Tolerance_in_Plants_Physiological_and_Biochemical_Mechanisms
<1% - https://link.springer.com/article/10.1007/s00709-005-0120-8
<1% - https://es.scribd.com/doc/92102973/TemasNutricionVegetal2009
<1% - http://europepmc.org/articles/PMC2803587
<1% -
https://scielo.conicyt.cl/scielo.php?script=sci_arttext&pid=S0718-34292009000200003
<1% - https://link.springer.com/article/10.1007/s12042-018-9199-x
<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6621490/
<1% - https://www.onlinejournal.in/IJIRV2I12/252.pdf
<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3728475/
<1% - https://www.hort.purdue.edu/rhodcv/hort640c/referen/stressm.htm
<1% - https://link.springer.com/chapter/10.1007/978-981-10-7461-5_17
<1% - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4537200/