REVIEW ARTICLE

DROUGHT AND SALINITY STRESS IN CROP PLANTS

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Abstract: Abiotic stress is a condition deviated from normal conditions which is mainly produced from the abiotic environmental factors or non living components. These factors affect the crop plants adversely via reducing growth and production. These non living components of environment are drought (water stress), water logging, extremes of temperature (high and low), high salinity/alkalinity, high acidity nutrient toxicity *etc.* Temperature (high and low), salinity stress and drought are major abiotic factor which affect much as compare to others non living factors. Abiotic stress severely limits plant growth and development, due to that final yield is reduced.

Keywords: Drought, Crop plants, Abiotic factor, Production

INTRODUCTION

According to world estimates (Wang *et al*., 2007), an average of 50% yield losses in agricultural crops are caused by abiotic factors. These comprise mostly of high temperature (40%), salinity (20%), drought (17%), low temperature (15%) and other forms of stresses (Ashraf *et al*., 2008). Only 9% of the world area is conducive for crop production, while 91% is afflicted by various stressors. As per the current estimates (ICAR, 2010), 120.8 million ha constituting 36.5 per cent of geographical area in India is degraded due to soil erosion, salinity/alkalinity, soil acidity, water logging, and other edaphic problems (Anonymous, 2015). In India, on an average of 50% yield losses in agricultural crops are caused by abiotic factors mostly shared by high temperature (20%), low temperature (7%), salinity (10%), drought (9%), and other forms of stresses (4%) (Anonymous, 2015). In this review we are considering only drought and salinity stress.

Drought: - Drought means the deficiency of water in soil or an imbalance in the plant water regime resulting in an excessive evapotranspiration from shoot over water uptake by root. Agricultural drought means that the soil moisture and rainfall are less or not sufficient during the growing season.

Response of plants to drought (Chaves *et al.* 2003, Larcher, 2003 and Kosova *et al.* 2014).

Drought escape: - It is based on the minimizing adverse effect of drought condition on a plant. In this mechanism plant completed its life cycle before drought. 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. It is also determines the ability of the crop to escape from climatic stresses including drought. 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). 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).

Drought avoidance:- It is based on minimizing the tissue dehydration by maintaining the high water potential in plant cells under limited water supply. Plant maximize water uptake by roots and minimize water loss by leaves. 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).

Drought tolerance:-It represents an adaptation of plant physiological functions under a limited water supply and decrease plant cell water potential in order to reach a sustainable balance between water uptake by roots and water release by shoots. Glaucousness or waxy bloom on leaves helps with maintenance of high tissue water potential, and is therefore considered as a desirable trait for drought

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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 ^{0}C cooler and had a lower rate of leaf senescence (Richards *et al.,* 1986). These authors suggested that a 0.5 ^{0}C reduction in leaf temperature for six hours per day was sufficient to extend the grain-filling period by more than three days. However, yield advantages are likely to be small as many varieties already show some degree of glaucousness.

Plant can resist drought conditions through (Choudhary *et al.* 2014)

Reduced water loss from aerial portion.

Increased water uptake from deep layers of the soil.

Giving more yield at low water potentials.

Effects of drought stress on plants

Drought stress results in stomatal closure and reduced transpiration rates, a decrease in the water potential of plant tissues, decrease in photosynthesis and growth inhibition, accumulation of abscisic acid (ABA), proline, mannitol, sorbitol, formation of radical scavenging compounds (ascorbate, glutathione, α-tocopherol etc.), and synthesis of new proteins and mRJNAs.

Mostly crops are affected by the drought stress due to the reduction in growth and development. Water loving crop like rice is probably more susceptible to drought stress than most other plant species. In pulses, the stem length was decreased under water deficit conditions like soybean (Specht *et al*., 2001) and *Vigna unguiculata* (Manivannan *et al.,* 2007a). The plant height was reduced up to 25% in water stressed citrus seedlings (Wu *et al.,* 2008). Stem length was significantly affected under water stress vegetables like potato (Heuer & Nadler, 1995) and *Abelmoschus esculentus* (Sankar *et al*., 2007 & 08). Water stress greatly suppresses cell expansion and cell growth due to the low turgor pressure. Osmotic regulation can enable the maintenance of cell turgor for survival or to assist plant growth under severe drought conditions in pearl millet (Shao *et al.,* 2008). The reduction in plant height was associated with a decline in the cell enlargement and more leaf senescence in *A. esculentus* under water stress (Bhatt & Rao, 2005). Development of optimal leaf area is important to photosynthesis and dry matter yield. Water deficit stress mostly reduced leaf growth in many species of plant like *Populus* (Wullschleger *et al.,* 2005) and soybean (Zhang *et al.,* 2004).

The importance of root systems is also observed during the drought stress. A prolific root system can confer the advantage to support accelerated plant growth during the early crop growth stage and extract water from shallow soil layers that is otherwise easily lost by evaporation in legumes (Johansen *et al*., 1992). The development of root system increases the water uptake and maintains requisite osmotic pressure through higher proline levels in *Phoenix dactylifera* (Djibril *et al*., 2005). An increased root growth due to water stress was reported in sunflower (Tahir *et al*., 2002). The root dry weight was decreased under mild and severe water stress in *Populus* species (Wullschleger *et al*., 2005). An increase in root to shoot ratio under drought conditions was related to ABA content of roots and shoots (Sharp and LeNoble, 2002). The root growth was not significantly reduced under water deficits in maize and wheat (Sacks *et al*., 1997).

Higher plant fresh as well as dry weights under drought conditions are desirable characters. A common adverse effect of drought stress on crop plants is the reduction in fresh and dry biomass production (Farooq *et al*., 2009). Plant productivity under drought stress is strongly related to the processes of dry matter partitioning and temporal biomass distribution (Kage *et al*., 2004). Reduced biomass due to drought stress was observed in almost all genotypes of sunflower (Tahir and Mehid, 2001). However, some genotypes showed better stress tolerance than the others. Mild water stress affected the shoot dry weight, while shoot dry weight was greater than root dry weight loss under severe stress in sugar beet genotypes (Mohammadian *et al*., 2005). Reduced biomass was seen in drought stressed soybean (Specht *et al*., 2001), *Poncirus trifoliatae* seedlings (Wu *et al*., 2008), common bean and green gram (Webber *et al*., 2006) and *Petroselinum crispum* (Petropoulos *et al*., 2008). A moderate stress tolerance in terms of shoot dry mass plants was noticed in rice (Lafitte *et al*., 2007).

The yield components like grain number and grain size were decreased under pre-anthesis drought stress treatment in wheat (Edward & Wright, 2008). In some other studies on maize, drought stress greatly reduced the grain yield, which was dependent on the level of defoliation due to water stress during early reproductive growth (Kamara *et al*., 2003; Monneveux *et al*., 2006). Water stress reduces seed yield in soybean usually as a result of fewer pods and seeds per unit area. In water stressed soybean the seed yield was far below when compared to well-watered control plants (Specht *et al*., 2001).

Water stress for longer than 12 days at grain filling and flowering stage of sunflower (grown in sandy loam soil) was the most damaging in reducing the achene yield in sunflower (Mozaffari *et al*., 1996; Reddy *et al*., 2004), seed yield in common bean and green gram (Webber *et al*., 2006), maize (Monneveux *et al*., 2006) and *Petroselinum crispum* (Petropoulos *et al*., 2008).

Drought stress produced changes in the ratio of chlorophyll 'a' and 'b' and carotenoids (Anjum *et al*., 2003b; Farooq *et al*., 2009). A reduction in chlorophyll content was reported in drought stressed cotton (Massacci *et al*., 2008). The chlorophyll content decreased to a significant level at higher water deficits in sunflower plants (Kiani *et al.,* 2008) and in *Vaccinium myrtillus* (Tahkokorpi *et al*., 2007). The foliar photosynthetic rate of higher plants is known to decrease as the relative water content and leaf water potential decreases (Lawlor and Cornic, 2002).

Drought stress affects the growth, dry mater and harvestable yield in a number of plant species, but the tolerance of any species to this menace varies remarkably. A ramified root system has been implicated in the drought tolerance and high biomass production primarily due to its ability to extract more water from soil and its transport to aboveground parts for photosynthesis.

Wheat yield under drought stress suffer serious moisture deficit throughout its growth period from seedling to full maturity (Bilal *et al*. 2015). Under drought condition decreasing pattern was experienced in morphologically yield contributing characters like plant height (PH), grains per spike, spikes per plant, 1000- grain weight (TGW) in wheat (Kilic and Yagbasanlar 2010). Blum and Pnuel (1990) reported that yield and yield contributing traits of wheat crop were drastically decreased under least annual precipitation**.** Drought stress lead to reduction in number of fertile tillers per plant, grains per spike and 1000-grain weight (TGW) which ultimately cause noticeably low grain productivity. Relationship between plant height (PH), leaf area and wheat grain yield has been noticed at booting and anthesis phase which cause improvement in grain yield under water deficit condition (Gupta *et al.* 2001). The decreasing graph in grain number was linked with reduced leaf area and lower photosynthesis as outcome of drought stress (Fischer *et al.* 1980).

According to the study of Dencic *et al.* (2000), wheat is paid special attention due to its morphological traits during drought stress including leaf (shape, expansion, area, size, senescence, pubescence, waxiness, and cuticle tolerance) and root (dry weight, density, and length). Lonbani and Arzani (2011), claimed that the length and area of flag leaf in wheat increased while the width of the flag leaf did not significantly change under drought stress. Leaf extension can also be limited under water stress in order to get a balance between the water absorbed by roots and the water status of plant tissues (Passioura, 1996). According to the study of Rucker *et al.* (1995), drought can reduce leaf area which can consequently lessen photosynthesis. Moreover, the number of leaves per plant, leaf size, and leaf longevity can be shrunk by water stress (Shao *et al.*, 2008). Singh *et al.* (1973) observed that leaf development was more susceptible to water stress in wheat. Root is an important organ as it has the capability to move in order to find water (Hawes *et al*., 2000). It is the first organ to be induced by drought stress (Shimazaki *et al*., 2005). In drought stress condition, roots continue to grow to find water, but the airy organs are limited to develop. This different growth response of shoots and roots to drought is an adaptation to arid conditions (Sharp and Davis, 1989; Spollen *et al*., 1993). To facilitate water absorption, root-to-shoot ratio rises under drought conditions (Morgan, 1984; Nicholas, 1998) which are linked to the ABA content of roots and shoots (Rane and Maheshwari, 2001). The growth rate of wheat roots was diminished under moderate and high drought conditions (Noctor and Foyer, 1998). In wheat, the root growth was not markedly decreased under drought (Rao *et al*., 1993). Plant biomass is a crucial parameter which was decreased under drought stress in spring wheat (Wang *et al*., 2005). The same outcomes were observed in previous studies in wheat and other crops (Watson, 1952; Sudhakar *et al*., 1993). In winter wheat, the yield was decreased or changed under drought and, in contrast, the water use efficiency was boosted (Xue e*t al*., 2006; Kahlown *et al.*, 2007).

For legumes, drought stress has adverse effects on total biomass, pod number, seed number, seed weight and quality, and seed yield per plant (Toker *et al.,* 2007b; Charlson *et al.,* 2009; Khan *et al.,* 2010; Toker and Mutlu, 2011; Impa *et al.,* 2012; Hasanuzzaman *et al.*, 2013; Pagano, 2014). Drought alone resulted in about a 40% reduction in soybean yield (Valentine *et al.*, 2011). Faba bean and pea are known to be drought-sensitive, whereas lentil and chickpea are known as drought-resistant genera (Toker and Yadav, 2010). Singh *et al.* (1999) arranged warm season food legumes in increasing order of drought tolerance: soybean < black gram < green gram < groundnut < Bambara nut < lablab < cowpea. Sinclair and Serraj (1995) reported that legumes such as faba (broad) bean, pea and chickpea export amides (principally asparagine and glutamine) in the nodule xylem are generally more tolerant to drought stress than cowpea, soybean and pigeon pea, which export ureides (allantoin and allantoic acid). The symbiotic nitrogen fixation (SNF) rate in legume plants rapidly decreased under drought stress due to (i) the accumulation of ureides in both nodules and shoots (Vadez *et al.*, 2000; Charlson *et al.*, 2009), (ii) decline in shoot N demand, (iii) lower xylem translocation rate due to a decreased transpiration rate, and (iv) decline of metabolic enzyme activity (Valentine *et al.*, 2011). Several reports have indicated that drought stress led to inhibition in nodule initiation, nodule growth and development as well as nodule functions (Vadez *et al.*, 2000; Streeter, 2003; Valentine *et al.*, 2011). The decrease in SNF under drought conditions was associated with the reduction of photosynthesis rate in legumes (Ladrera *et al.*, 2007; Valentine *et al.* 2011). In many nodules of legumes, water stress resulted in stimulation of sucrose and total sugars (Gonzalez *et al.*, 1995, 1998; Ramos *et al.*, 1999; Streeter, 2003; Galvez *et al.*, 2005; Valentine *et al*,. 2011). This was consistent with a study on pea mutants, which showed that sucrose synthase (SS) is essential for normal nodule development and function (Craig *et al.,* 1999; Gordon *et al.,* 1999). Drought stress induces oxidative damage in legumes and this has a harmful effect on nodule performance and BNF (Arrese-Igor *et al.,* 2011). Some reports suggest that nodules having an increment in enzymatic antioxidant defence can display a higher tolerance to drought/ salt stress in common bean (Sassi *et al.,* 2008) and chickpea (Kaur *et al.,* 2009). In addition to this, Verdoy *et al.* (2006) reported improved resistance to drought stress in *Medicago truncatula* by overexpression of Δ-pyrroline- 5-carbolyate synthetase resulting in accumulation of high proline levels.

Salinity stress

Salinity means a condition of soil with high concentration of soluble salts. Salinity stress means that this condition disturbs the normal growth and development of plants which ultimately reduce final yield. Salinity is one of the most serious factors limiting the productivity of agricultural crops, with adverse effects on germination, plant vigour and crop yield. Salinization affects many irrigated areas mainly due to the use of brackish water. Worldwide, more than 45 million hectares of irrigated land have been damaged by salt, and 1.5 million hectares are taken out of production each year as a result of high salinity levels in the soil (Munns & Tester, 2008).

High concentration of salts effect plants mainly by creating two conditions

High concentration of salts in soil solution: It creates difficulty to plant roots to extract water from soil solution. It also affect the cell growth and development due to that plant suffer from the salt stress. It causes osmotic stress which affects the rate of shoot growth.

High concentration of salts with in plant: This high salt condition toxic for plant. It takes time to accumulate salts inside the plants and after that it will affect plant functions adversely.

Response of plants to salinity stress: - Plant species vary in how well they tolerate salt-affected soils. Some plants will tolerate high levels of salinity while others can tolerate little or no salinity. In cereals rice is more sensitive to salinity and barley is the most tolerant crop.

Osmotic adjustment: - Osmotic adjustment in plants subjected to salt stress can occur by the accumulation of high concentrations of either inorganic ions or low molecular weight organic solutes. The compatible osmolytes generally found in higher plants are low molecular weight sugars, organic acids and nitrogen containing compounds such as amino acids, amides, amino acids, proteins and quaternary ammonium compounds. The growth of salt-stressed plants is mostly limited by the osmotic effect of salinity, irrespective of their capacity to exclude salt that results in reduced growth rates and stomatal conductance (Fricke *et al.*, 2004 & James *et al.*, 2008). In fact, osmotic tolerance involves the plant's ability to tolerate the drought aspect of salinity stress and to maintain leaf expansion and stomatal conductance (Rajendran *et al.*, 2009). At the end, while the mechanisms involved in osmotic tolerance related to stomatal conductance, water availability and therefore to photosynthetic capacity to sustain carbon skeletons production to meet the cell's energy demands for growth have not been completely unraveled, it has been demonstrated that the plant's response to the osmotic stress is independent of nutrient levels in the growth medium (Hu *et al*., 2007).

Salt secretion: - In many halophytes, another important salt resistance mechanism is salt secretion, which regulates salt tolerance by secreting salt (especially NaCl) through salt glands in the leaves and by modulating the internal ion concentrations to a lower level. Na^+ exclusion by leaves ensures that Na does not accumulate to toxic concentrations within leaves. In the majority of plant species grown under salinity, Na^+ appears to reach a toxic concentration before Cl^- does, and so most studies have concentrated on Na^+ exclusion and the control of Na^+ transport within the plant (Munns & Tester, 2008). Therefore, another essential mechanism of tolerance involves the ability to reduce the ionic stress on the plant by minimizing the amount of Na^+ that accumulates in the cytosol of cells, particularly those in the transpiring leaves. This process, as well as tissue tolerance, involves up- and down regulation of the expression of specific ion channels and transporters, allowing the control of Na^+ transport throughout the plant (Munns & Tester, 2008 & Rajendran *et al.* 2009). Na^+ exclusion from leaves is associated with salt tolerance in cereal crops including rice, durum wheat, bread wheat and barley (James *et al*., 2011). Exclusion of Na^+ from the leaves is due to low net Na^+ uptake by cells in the root cortex and the tight control of net loading of the xylem by parenchyma cells in the stele (Davenport *et al.*, 2005). Na^+ exclusion by roots ensures that Na^+ does not accumulate to toxic concentrations within leaf blades. A failure in Na^+ exclusion manifests its toxic effect after days or weeks, depending on the species, and causes premature death of older leaves (Munns & Tester, 2008).

Salt compartmentalization: - The capacity for ion compartmentalization among different tissues and cells is the key mechanism regulating salt tolerance in plants. Tolerance requires compartmentalization of Na^+ and Cl^- at the cellular and intracellular level to avoid toxic concentrations within the cytoplasm, especially in mesophyll cells in the leaf. Many processes operate to enable plants to balance Na^+ concentrations in their different organs, cell types and subcellular compartments to optimize growth and development under the given environmental conditions. Generally, the primary tissue in which

Na^+ toxicity is manifested is the mature leaf (Munns, 2002). The toxicity of Na^+ at agronomically relevant Na^+ concentrations has often been associated with the extent of Na^+ accumulation in leaves (Munns, 1993).

Effects of salinity stress on plants: In cereals, salinity reduces the number of tillers due to that total leaf area is reduced and ultimately final yield is reduced. In pulses, size of leaves and number of branches reduced due to salinity. The decreased rate of leaf growth after an increase in soil salinity is primarily due to the osmotic effect of the salt around the roots. A sudden increase in soil salinity causes leaf cells to lose water, but this loss of cell volume and turgor is transient. Within hours, cells regain their original volume and turgor owing to osmotic adjustment, but despite this, cell elongation rates are reduced (Passioura and Munns, 2000). Over days, reductions in cell elongation and also cell division lead to slower leaf appearance and smaller final size. Cell dimensions change, with more reduction in area than depth, so leaves are smaller and thicker. The most dramatic and readily measurable whole plant response to salinity is a decrease in stomatal aperture. Stomatal responses are undoubtedly induced by the osmotic effect of the salt outside the roots. Salinity affects stomatal conductance immediately, firstly and transiently owing to perturbed water relations and shortly afterward owing to the local synthesis of ABA (Fricke *et al.*, 2004).

Seed germination and seedling growth of crops under saline conditions is generally affected due to high osmotic pressure of the solution. Salinity affects time and rate of germination in crops (Mudgal, 2004). Salinity is a major abiotic stress limiting germination, plant vigour and yield of agricultural crops especially in arid and semi-arid regions (Munns and Tester, 2008; Abdel Latef and Chaoxing, 2011; Aggarwal *et al.*, 2012; Ahmad and Prasad 2012a, 2012b; Porcel *et al.*, 2012; Kapoor *et al.*, 2013). Approximately 20% of irrigated land worldwide currently is affected by salinity, particularly in arid and desert lands, which comprise 25% of the total land area of our planet (Yeo, 1999; Rasool *et al.*, 2013). High salinity affects plants in several ways: water stress, ion toxicity, nutritional disorders, oxidative stress, alteration of metabolic processes, membrane disorganization, reduction of cell division and expansion, and genotoxicity (Hasegawa *et al.*, 2000, Munns, 2002; Zhu, 2007; Shanker and Venkateswarlu, 2011; Gursoy *et al.*, 2012; Djanaguiraman and Prasad, 2013). Together, these effects reduce plant growth, development and survival (Rasool *et al.*, 2013; Hameed *et al.*, 2014). Food legumes are relatively salt sensitive compared with cereal crops, thus farmers do not consider growing food legumes in salinized soils (Saxena *et al.*, 1993; Toker and Mutlu, 2011; Egamberdieva and Lugtenberg, 2014). The sensitivity in legumes may be due to salt affecting bacterial activity and nitrogen fixation (Materne *et al.*, 2007; Toker *et al.*, 2007a; Toker and Mutlu, 2011; Egamberdieva and Lugtenberg, 2014). Salt stress led to reduction in shoot growth of soybean, chickpea, pea, faba bean and mung bean plants (Elsheikh and Wood, 1990, 1995; Delgado *et al.*, 1994; Hussain *et al.*, 2011; Saha *et al.*, 2010; Rasool *et al.*, 2013). The response of BNF in contrasting tolerance lines of *Medicago ciliaris* to salt stress did not show a clear trend in relation to nodule carbohydrate metabolism (Ben-Sala *et al.*, 2009). Nodules of common bean (Sassi *et al.*, 2008) and chickpea (Kaur *et al.*, 2009) display a higher tolerance to osmotic/salt stress due to increased enzymatic antioxidant defence (Arrese-Igor *et al.*, 2011). Salinity stress significantly decreased the activities of nitrogenase and phosphate enzymes (acid and alkaline) in faba bean (Rabie *et al.*, 2005; Hussain *et al.*, 2011). The effect of salinity stress on growth and some metabolic activities of mung bean were investigated by Saha *et al.* (2010). They concluded that salinity stress suppressed the early growth of mung bean seedlings. Salinity also damaged the photosynthetic machinery by causing reduced chlorophyll content, and also induced the accumulation of proline, malondialdehyde (MDA) and H_2O_2 in roots and leaves of mung bean plants. Furthermore, salinity stress caused increments in the activity of superoxide dismutase (SOD), catechol peroxidase (CPX) and catalase (CAT) in root and leaves of mung bean plants. Recently, Rasool *et al.* (2013) reported that tolerance of chickpea genotypes (SKUA-06 and SKUA-07) to salinity seems to be related to the efficiency of the enzymatic antioxidants SOD, CAT, ascorbate peroxidase (APX) and glutathione reductase (GR) against accumulation of reactive oxygen species (ROS), which would maintain the redox homeostasis and integrity of cellular components.

Nutrient disturbances under salinity reduce plant growth by affecting the availability, transport, and partitioning of nutrients. However, salinity can differentially affect the mineral nutrition of plants. Salinity may cause nutrient deficiencies or imbalances, due to the competition of Na^+ and Cl^- with nutrients such as K^+, Ca_2^+, and NO_3^-. Under saline conditions, a reduced plant growth due to specific ion toxicities (e.g. Na^+ and Cl^-) and ionic imbalances acting on biophysical and/or metabolic components of plant growth occurs (Grattan and Grieves, 1999). Increased NaCl concentration has been reported to induce increases in Na and Cl as well as decreases in N, P, Ca, K and Mg level in fennel (Abd El-Wahab, 2006); *Trachyspermum ammi* (Ashraf and Orooj, 2006); peppermint and lemon verbena(Tabatabaie and Nazari, 2007), *Matricaria recutita* (Baghalian *et al.*, 2008), *Achillea fragratissima* (Abd EL-Azim and Ahmed, 2009).

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