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CLIMATE CHANGE : COMBATING DROUGHT WITH ANTITRANSPIRANTS AND SUPER ABSORBENT

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Abstract

Climate change is impacting weather in many different ways. In subtropical region like ours, it is found responsible for drought and temperature rise in coming future. This will drastically bring down the production, if we will not start looking for other possibility to increase WUE (water use efficiency) to cope up with water stress conditions. Here, in this review we are putting efforts to interpret the use of antitranspirants and superabsorbent. With the help of these there are chances of conserving irrigation water, aiding plant survival under dry conditions, and protecting foliage against fungus, insects, smog, and salt spray.

Antitranspirants are the chemical compound which favours reduction in rate of transpiration from plant leaves by reducing the size and number of stomata and gradually hardening them to stress. They are categories into film-forming, stomatal-regulating and reflective compounds based on mode of their work. There are many chemical which are studied for being effective antitranspirants *viz*., chitosan, magnesium carbonate, salicylic acid and kaoilin etc. However, there are possibilities of growth reduction due to effect of stomatal closure on gaseous exchange, but still they are among promising substances which can help under water deficit soil environment.

Another aspect of combating is improving water holding capacity of soil continuum. One of the means to increase the water content in this soil is the use of super absorbent polymers as soil conditioners, which increase water retention in root zones region of the soil. These super absorbent polymers are compound that absorb water and swell into many times of their original size and weight. SAP can play a vital role in stress alleviation at appropriate time as needed by the plants.

Key words : Antitranspirants, SAP (super absorbent polymers), WUE (Water use efficiency), chitosan and drought.

Introduction

Climate change needs no introduction any more with well known effect on different aspect of life including agriculture and food production (Kang, 2009). Almost every part of the world evidenced its impact at different level and affected either positively or negatively. India being subtropical country is also sighting various changes in weather pattern and temperature rise that have effect on agriculture production. Water is necessary component for plant's growth and development (Rijsberman, 2008). Rainfall and irrigation are the two main sources of water in agriculture. Rain-fed crops contribute to 65% of world food production and the remaining 35% of food is produced from irrigation agriculture. Only 17% of total cultivated areas are irrigated (Rosegrant, 2010 and Hanjra, 2010). Thus, most of the land under cultivation depends on natural precipitation. Thus shifting in global rain pattern and increase in local temperature is leading to unprecedented drought in many crop production areas of the world (FAO, 2008).

In Uttar Pradesh of India, almost once in every third year in western part and once in five years in eastern part, drought is experienced in past few years (NIDM UP, 2012). Normal rainfall was recorded in only in one year (2008-09) in past decades (947mm), and average annual rainfall decreased from 947mm to 737 mm. Further, of the total 10 years, 6 years received even below the decadal average *i.e*., 737mm (SAPCC, 2014). The distribution of seasonal rainfall has been highly erratic affecting cropping pattern, selection of crops and their varieties and over all agricultural production (Rosegrant,

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2010). Changes in climate variables like temperature increases can affect the hydrologic cycle by directly increasing evaporation of available surface water and vegetation transpiration. In past decades the average temperature of eastern utter Pradesh is rise. The minimum and maximum temperature is increase, which is around 2.0°C towards 2050. Whereas the average rainfall is also decrease in recants time period (IPCC, 2007). Rise in minimum temperature is appreciably higher than that maximum temperature, increasing in temperature and low rainfall causes drought prone condition in coming years in utter Pradesh, which is directly, affects on agriculture production (SPACC, 2014).

To cope-up with coming vulnerability in agriculture production there are certain strategies which includes improvement in water use efficiency through irrigation, rain water harvesting and agronomic practices like mulching (Evans, 2008). Besides traditional efficient irrigation systems like drip irrigation, sprinkler irrigation recent research exploring possibilities towards use of certain environmentally friendly chemical which may increase water holding capacity of soil or may reduce the rate of transpiration (antitranspirants), which will make varieties withstand under water deficient condition and application can be managed on requirement bases. Which means when we need to slower down the transpiration when can apply antitranspirants and similar strategies can be adopted for increasing soil water retention capacity. Most of the crop plants presently cultivated lack physiological adaptation to hold out under water stress (Guillen *et al*., 2013). Present review seeks out the possibilities of use of antitranspirants and super absorbent.

Antitranspirants

Antitranspirants are the chemical compound which favours reduction in rate of transpiration from plant leaves by reducing the size and number of stomata and gradually hardening them to stress (Ahmed *et al*., 2014; El Khawaga, 2013). Nearly 95-98% of the water absorbed by the plant is lost in transpiration (Prakash and Ramachandran, 2000; Gaballah, 2014). It is a substance involved in increasing drought stress resistance. Foliar sprays markedly increase all growth parameters and Relative Water Content and may reduce transpiration in three different ways: (1) some chemicals reduce the absorption of solar energy and decrease leaf temperatures and transpiration rate; (2) certain chemicals (wax, latex or plastics) form thin colourless transparent films which decrease the escape of water vapour from the leaves but not affect the gasses exchange and (3) certain chemical compounds can control stomatal opening (by affecting the guard cells around the stomatal pore), thus decreasing the loss of water vapour from the leaves, (Besufkad *et al*., 2006). Water stress are substantially impacts yield. Hence, the application of Antitranspirant immediately prior to this stage may conserve water and improve grain set which could outweigh the photosynthetic limitations (Kettlewell *et al*., 2010).

The three general types of antitranspirants are : (1) film-forming (2) stomatal-regulating and (3) reflective compounds.

Film-forming compounds

Film forming antitranspirant form a colourless film on the leaf surface which reduces the transpiration rate but have no effect on gasses exchange (Gale, 1961). Study of film on leaf surface by Slatyer and Bierhuizen (1964), Nitzshe (1991) resulted that the formation of film on surface of leaves reduces greater extent transpiration but a little bit affected on growth. Gale and Hagan (1966) also reported that mostly film-forming compounds are stop loss of water vapor and less effective to CO_2 (Davenport *et al*., 1969) found it that coating of leaves by "CS-6432" alleviated photosynthesis more than transpiration when applied to plant. Past studies proved that the film forming antitranspirant is more effective in increasing grain yield and increasing photosynthesis in both, adverse or favourable condition. The higher leaf turgor in AT-sprayed WD (water deficit) plants is consistent with the notion that AT film decreases water loss and enables prolonged turgor maintenance under WD conditions In water stress condition leaf maintain its turgidity by applying antitranspirant on it and reduce the water loss in stress condition (Amor *et al*., 2010).

Fig. 1 : Leaf showed the application of film forming antitranspirant (colourless film) on leaf surface (Budke *et al*., 2013).

Application of antitranspirant may improve growth and physiological response in water and high temperature stress in plants (Leskovar *et al*., 2008, 2011), water stress at a flowering stage affect the yield component of crop, it may be decrease, hence the foliar spray of antitanspirant is help in improving the photosynthesis and reduces the transpiration rate which causes a better production in crops (Kettlewell *et al*., 2010).

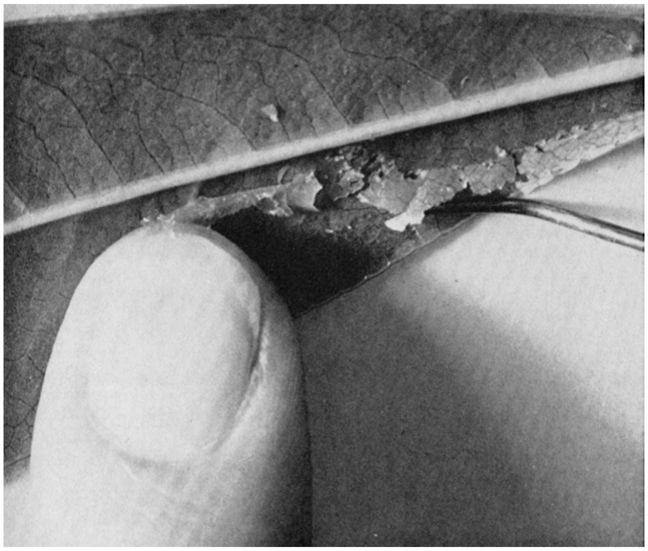


Fig. 2 : Film-forming antitranspirant (polyvinyl chloride complex) was applied to the entire leaf surface but only that portion of the film loosened by the needle is visible in photo (Davenport, 1970).

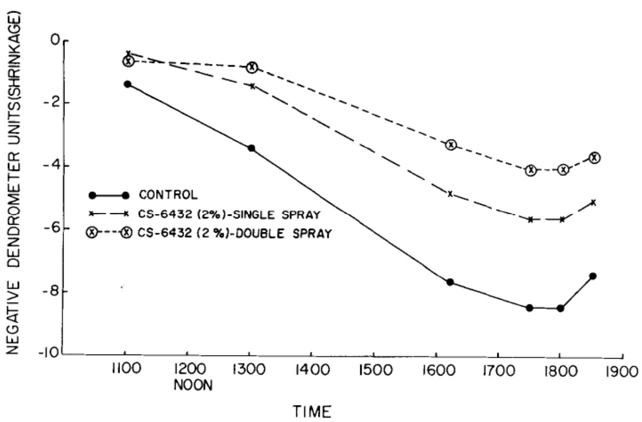


Fig. 3 : Effect of experimental film forming Antitranspirants as a single or a double foliar spray on the day time shrinkage of almond tree trunk (Davenport, 1970).

Stomatal regulating compound

Most of the anti transpirant functions as stomatal closer compound when it applied over leave. Some fungicide like phenyl mercuric acetate (PMA) and herbicide like Atrazine in low concentration serve as anti transpirant by inducing stomatal closing (Zelitch, 1961). These might reduce photosynthesis PMA was found to decrease transpiration than photosynthesis (Zelitch and Waggoner, 1962). Initial investigations professed that certain fungicides including phenyl mercury acetate (PMA), mercurized copper oxychloride, and copper oxychloride reduced the transpiration of tomato seedlings and potato plants (Blandy, 1957). Many effective stomatal-regulating compounds and also their concentrations used, the percent decrease in transpiration and stomatal condition; phenyl mercuric acetate, 8-hydroxyquinoline sulphate, and the mono-methyl ester of decenylsuccinic acid appeared to be the highly effective compounds (Zelitch, 1968). Since stomatal apertures affect CO_2 diffusion as well as water vapour flow, photosynthesis and growth may be change when stomatal regulating compound are applied on leaves surface. If stomatal apertures are reduces in their size, transpiration should be also reduced by a greater amount than photosynthesis (Waggoner, 1965). Changes in transpiration (T) and photosynthesis (P) due to changes in stomatal path length (S) which was described by Zelitch and Waggoner (1962).

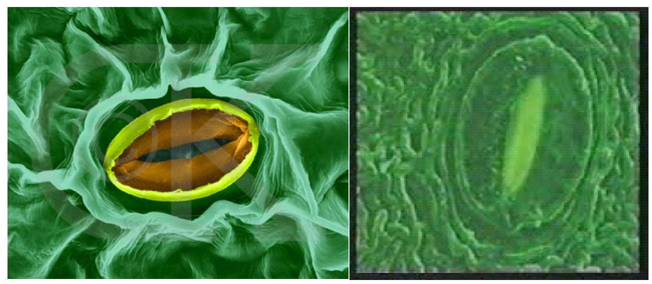


Fig. 4 : Image showing the stomatal activity after application of stomatal regulating compound (Buckley *et al*., 2013).

Reflectance compound

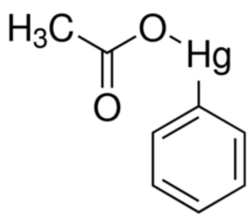
White material which reflects solar radiation and increase the leaf albedo when they applied on leaves surface. Reflecting compounds do not cause blockage of stomatal pores when they are applied to the upper surfaces of leaves with stomata exclusively on the lower surfaces. Coating of reflectance type of chemical reduce the leaf temperature. It was experimentally proved that we diminished a transpiration rate up to 22-28% and also reduced leaf temperature 3^o to 4^o after coating of kaolinite (225 mg dm^{-2}) (Hagan and Davenport, 1970). Some chemical compounds decrease leaf temperature by reflecting the solar radiation which cause retard transpiration rate and increase the water use efficiency of crops (Bittelli *et al*., 2001; Moftah and Humaid, 2005; Jifon and Syvertsen, 2003).

Chemical which is use as antitranspirants:

1) Chitosan
2) Kaolin
3) Abscisic acid (ABA)

4) Salicylic acid
5) Phenyl mercuric acetate
6) Cycocel 7) $MgCO_3$
8) $CaCO_3$, etc.

Phenyl mercuric acetate



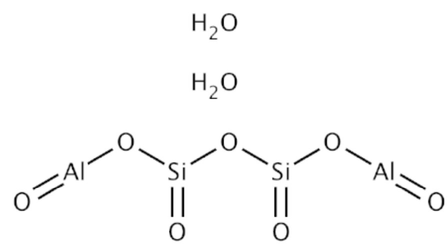
Phenyl mercuric acetate is example of such chemical compounds which affected on regulation of stomata or controlling the activity of stomata by changing their metabolic activity and permeability. Phenyl mercuric acetate is an organ mercury compound and in past research its activity reported as a antitranspirant when applied to the leaves surface (Ouda, 2007). In agriculture the phenyl mercuric acetate use as pesticide and it must be used with care since, it is mercury contain metabolic inhibitor. PMA is act as stomatal closer compound the optimum conc. may vary 10^{-3}(strong) 10^{-5} (dilute). *Betula papyrifera* leaves treated with 10^{-3} m & 10^{-4} m PMA showed at least a certain degree of browning. By compression leaves treated with 10^{-5} m PMA had the same appearance as the control. The chlorophyll content PMA treated leaves is decreased by 25%.the action of magnesium carbonate as a refelectant, which helped in reducing heat load on leaves and increased penetration of more solar radiation into the canopy for photosynthesis (Gaballah and Moursy, 2004).

Chitosan

Chitosan is a non toxic muco-polysaccharide with antimicrobial activity, which help plant to its defence system, it is found by de-acetylazation of chitin which is structural component of exoskeletons of crustaceans and some of the insects (Sanford, 2003). It is experimentally proved that chitosan increased the chlorophyll pigments under drought stress, its cleared that chitosan can induced the rate of photosynthesis and the accumulation of organic matter in wheat seedlings. chitosan can enhance the root development in under water deficit condition, which help in absorbing more water to keep the moisture stable (Zhang *et al*., 2002).

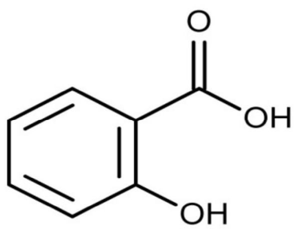
Chitosan has a strong potential application value in agriculture. Study of stomata under electron microscope and the histochemical analysis is proved that the coating of leaf by chitosan is close the stomata either partial or full and inhibit the water loss by leaf (Bittelli *et al*., 2001). Chitosan May take a part in ABA biosynthesis, which is responsible for stomatal closer in water defect condition in plants. The formation of chitosan films on the waxy surface of plant leaves prompts their use as antitranspirant. Chitosan works as both film-forming compound and physiological regulator of stomata via the ABA-dependent pathway (Kumar, 2013). Some film-forming compounds, like chitosan increase leaf surface reflectance, reducing absorption of radiant energy (heat), lowering leaf temperature, reducing water evaporation within the leaf and its diffusion to the surrounding atmosphere (referred to as transpiration). Stomata are the main route of water vapour export during plant growth. When emulsions of the synthetic compounds are sprayed on leaf surface, they form thin films and limit gas exchange by increasing stomatal resistance to the diffusion of water vapour (Jardin, 2012).

Kaolin



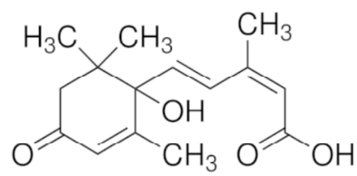
Foliar application of kaolin has been demonstrated that it reduce the negative effects of water stress and to improve the physiology and productivity of plants (Rosati *et al*., 2006). The use of kaolin enhance the photosynthetic rate under water-stress conditions by increasing photosynthesis pigments in plants, under low water condition the application of kaolin may improve the photosynthetic response and increase the photosynthetic pigments (Monroy, 2012) and help in enhancing the water potential and osmotic potential in plants (Moftah and Humaid, 2005). It also increases the water-use efficiency of plants by 25% (Glenn *et al*., 2010). 1 to 6% kaolin treatment are gives better response in under unfavarable condition which inhibit the rate of transpiration and improve the yield quality (Jifon and Syvertsen, 2003). Several kaolin clay treatment are make a colourless film over the leaf surface which reflect the high wave length of solar radiation and retarded high temperature stress and water loss and also enhance the productivity of the plant (Mon, 2013). Kaolin is help in reduce heat effect and also protect leaf from sunburn, but it may slightly affect on ionic balance of soil. Application of kaolin is decrease leaf temperature 3 to 4°C and also mitigate the loss of water from leaf surface of 22 to 28 % in many species and increase the leaf relative water content in plants and promotes the photosynthetic activity, which results increasing in biomass production (Khalil, 2012). Soil moisture percentage and antitranspirants significantly influenced the daily transpiration rate water use efficiency was increased at low soil moisture and by antitranspirants (Hagan and Davenport, 1970). The relative water content of leaves was reduced by low soil moisture, but was increased by the application of antitranspirants, which relieved plant water stress (Patil, 1976).

Salicylic acid (SA)



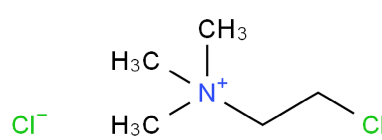
0.5% of salicylic acid increase the chlorophyll, no. of fruits, antioxidants enzymes which plays a defence mechanism against the moisture stress condition and all other parameters of growth (Ahmed, 2014). In earlier study it is reported by (Larque, 1978), the application of salicylates can mitigate the rate of transpiration and prevent the water loss from stomata (Mishra, 2015), the salicylic acid work as signal transduction whose activate the ABA activity and responsible for stomata closure in plants. This activity of stomata can effects on other physiological phenomenon like the stomatal closure may affect the photosynthetic process, SA shows its effect on chlorophyll, respiration, but most probably involved in regulation of photosynthetic reaction. It is demonstrated by Pancheva *et al*. (1996), 5 to 7 days of treatment of salicylic acid induced the CO_2 level in leaf because of the stomatal closure (which effect the gassause exchange) and inhibit the activity of RuBP carboxylase which is effect on photosynthesis phenomenon, but 1 or less than 1 day treatment of SA did not show effect either on any physiological or biochemical parameters of crop. Activities of H_2O_2-metabolizing enzymes (such as CAT, POD and APX) and superoxide-dismutating enzymes (SOD) were also modulated with SA in plants exposed to drought (Saruhan *et al*., 2012). SA (500 μM)-supplementation to drought stressed *H. vulgare* resulted in increased net CO_2 assimilation rate due to increased stomatal conductance and eventually in increased plant dry mass (Habibi, 2012). Exogenously applied SA can modulate important enzymatic (including monodehydroascorbate reductase, MDHAR; dehydroascorbate reductase, DHAR; GR; GSH peroxidase, GPX) and non-enzymatic (including GSH) components of AsA–GSH pathway, and also glyoxalase system (Gly I and Gly II) and decrease oxidative stress in drought-exposed plants (Abbaspour *et al*., 2016). Foliar application of SA (1.0 ìM) strengthened antioxidant defence system in drought-tolerant *Z. mays* cultivar to a great extent (vs. drought-sensitive cultivar; (Saruhan *et al*., 2012). Low membrane lipid peroxidation but increased plant height and dry mass, and less wilting of leaves were reported in drought-exposed and SA (0.5 mM)-supplemented *T. aestivum* (Kang *et al*., (2012). Recently, SA-biosynthetic enzymes (such as CS and ICS) were not correlated with the SA level, but ortho-hydroxy-cinnamic (oHCA) was correlated with SA biosynthesis and played crucial role in drought tolerance in *O. sativa* (Pál *et al*., 2014).

Abscisic acid (ABA)



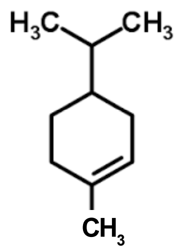
Abscisic is a plant growth substance, which play as a important part in response in environmental sttress and plant pathogens (Giraudat, 1998). When water potential of soil is decreased, it produced in roots and translocates to leaves where, it rapidly alters the osmotic potential of stomatal cells causing them to shrink and stomata to close. ABA induced stomatal closer retarded transpiration, thus preventing further water loss from the leaves in time of low water availability (Kang, 2002). 0.5 mg/l concentration of the ABA through prevent it from chilling stress, and also help in to decrease water loss in tomato plant and it also reduced the water stress effect in artichoke after applying it on surface of leaves by stomata closing (Takahashi *et al*., 1993).

Cycocel



It is demonstrated that stomata show a significant role under water stress condition, to cope up from water stress stomata gets close for conserving water and this activity of stomata effect on gaseous exchange in PSII (Souza *et al*., 2004). This stomatal regulation under drought stress retard the actual photosynthetic rate. the application of cycocel (CCC) under water stress condition reduced the water loss from the areal part of plant and increase the yield and vegetative growth, which are helpful tools in reducing transpiration losses, is becoming popular (Rouhi *et al*., 2007). Cycocel with 500ppm concentration may help to mitigate the drought stress and significantly increase the photosynthetic pigment (Memari *et al*., 2011). Cycocel also act as growth inhibitor, foliar application of CCC reduce transpiration but, it may be lil bit affect the growth of plant (Pandey *et al*., 2003).

Pinolene



Pinolene is an example of film forming antitranspirant, which did not increase water use efficiency of crop, but it can prevent water loss from arial part of plant. But, it is proved that the application of pinolene on grapes plant can increase both the WUE as well as sugar and anthocyanin content by which the quality of wine may also improve it may not possible with other substance at the same time. Pinolene helps in stomatal regulation and also decrease the photosynthesis (Brillante, 2013; Amor, 2010; Palliotti, 2010).

Dyroton

Drought has been considered as one of the most acute abiotic stresses presently affecting agriculture. Drought stress can significantly reduce photosynthesis and stomatal conductance, inhibit photosynthetic pigments synthesis and ultimately lead to reduction in growth of plants (Basu, 2016). The plant treated with 1-2% of the dyroton show very effective response in yield component of plant, and it increasing the nutritional value in fruits. It also prevents fruits with pathogenic response after postharvest (Faten, 2008).

Effect of antitranspirant

Stomata is responsible for both the photosynthesis (by intake CO_2 from atmosphere) as well as transpiration (loss of water) the antitranspirant is play a important role for reducing water loss and conserve the water but, it may be shows some effect on growth of plant (Obidiegwu *et al*., 2015). Some of the antitranspirant is not responsible for stomata closing when it applied to both the leaf surface upper and lower, but it may be responsible for the deduction of photosynthesis when light is not available in properly (Latocha *et al*., 2009). It is experimentally proved that the application of antitranspirant is helpful for the reduction of water loss and these chemical do not show adverse effect or harm plant's intramural photosynthetic machinery. Phenyl mercuric acetate is a chemical, which is use as antitranspirant which close the stomata after application ant the intermediate concentration of PMA (1-3.5 M) is retard the rate of transpiration but it may reduce the dry matter of the plant. But, it is also reported that the higher concentration of PMA (10- 13.2 M) is shows the toxic effect on plant which retire the dry matter production and also increase transpiration (Abdullah, 2015).

In general field crops are highly dependent or current photosynthesis for growth and final yield. Therefore, it is unlikely that currently available antitranspirant would increase yield of an annual crop unless crop suffers stressed from inadequate water and or a very high evaporative demand, particularly during a moisture sensitive stage of development. Sprayed stomata inhibiting or film forming antitranspirants on field grown sorghum under limited irrigation conditions, he found that grain yield increases 5 to 17% and application of antitranspirant just before the boot stage was more effective than later sprays (Fuahring, 1973).

Disadvantages of antitranspirants

The possibility of using antitranspirants on grass to reduce both the frequency of irrigation and mowing is an attractive prospect which merits further investigation. The use of antitranspirants to decrease transpirational water losses from shrubs and trees on watersheds, where increased water yields may be more important than any harm caused by growth reductions, is a promising field for research and studies (Davenport, 1970).

Growth reductions from the use of antitranspirants should not be disadvantageous once the oleanders have attained a height effective for screening headlight glare. Growth retarded growth is retarded by natural stomata1 closure when an untreated plant wilts, because of low soil water potentials and/or high evaporative demand. By slowing down the rate at which water is lost, antitranspirants will help to prevent or at least will delay wilting.

The use of an antitranspirant, and the resulting reduction in transpiration (which is unlikely to exceed 30 per cent under field conditions), should not reduce the rate of mineral supply to the leaves sufficiently to retard growth. Present evidence suggests that antitranspirants will affect growth much less by altering leaf temperature and mineral nutrient supply than by retarding carbon dioxide supply to leaves.

Super absorbent polymers

Super absorbent polymers (SAP's) are a unique group of materials that can absorb over a hundred times their weight in liquids and do not easily release the absorbed fluids under pressure. Super absorbents were first developed by the United States Department of Agriculture in the late 1960s. Early commercial versions first emerged in the United States in the early 1970s in the form of starch/acryonitril/acrylamide based polymers (Yamaguchi *et al*., 1987), with applications originally focused in the agriculture/horticulture markets, where they were used as a hydro gels to retain moisture in the surrounding soil during growing and transportation. Subsequently, cross-linked polyacrylates and modified cellulose ethers were also commercialized along with starch-grafted cross-linked polyacrylates. Polymers were used as structural materials for creating a climate beneficial to plant growth. One of the means to increase the water content in this soil is the use of super absorbent polymers as soil conditioners, which increase water retention in root zones region of the soil. In agricultural field, polymers are widely used for many applications. Although, they were used initially, just as structural materials, in the last decades, functionalized polymers revolutionized the agricultural and food industry with new tools for several applications.

Super absorbents, depending on their source and structure are divided in two main groups of natural and synthetic.

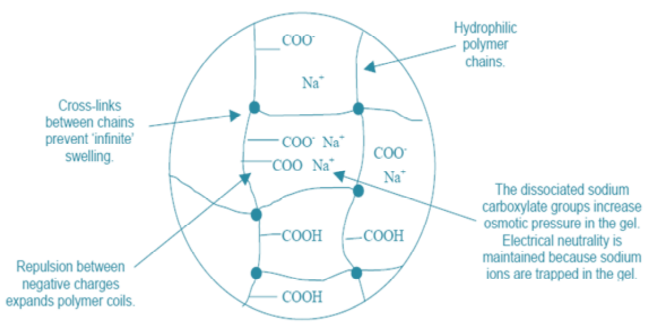


Fig. 5 : Shows diagrammatic representation of part of the polymer network, cross-linking of polymers. The polymer backbone in SAP is hydrophilic *i.e.* 'water loving' because it contains water loving "carboxylic acid" groups (– COOH) (Elliot, 2010).

Natural-based SAPs are usually prepared through addition of some synthetic parts onto the natural substrates, *e.g.*, graft copolymerization of vinyl monomers on polysaccharides, humus, polyuronids, Aljinic acids and starch (Lanthong *et al*., 2006; Li *et al*., 2007), cellulose (Suo *et al*., 2007), chitosan (Mahdavinia *et al*., 2004; Zhang *et al*., 2007), guar gum (Wang and Wang, 2009) and gelatin (Pourjavadi *et al*., 2007).

Synthetic SAPs : The greatest volume of SAPs comprises full synthetic or of petrochemical origin. They are produced from the acrylic monomers, most frequently acrylic acid (AA), its salts and acrylamide (AM). Synthetic polymers with net type chemical bonds are not dissolvable in water. Synthetic SAPs usually are either polyveneyl alcoholes $(-CH_2OHOH-)n$ or polyacrylamides $(-CH_2CHCONH_2-)n$. SAPs used in agriculture are usually formulations commonly made of starch polyacrylamid graft copolymers (starch copolymers: SCP), venylalcohol-acrylic acids (copolymers: PVA), and acrylamids sodium acrylate copolymers (polyacrylamides: PAM) (Peterson, 2002). Synthetic polymers are used more than natural polymers because they are more resistant to biological degradation (Peterson, 2002).

Physical Properties of Monomers for preparing Super absorbent Polymers

The monomers, which are useful for making superabsorbent polymers are water-soluble monomers. Acrylic acid, methacrylic acid and 2-acrylamido-2-methylpropanesulfonic acid are the principal ionizable monomers useful for making superabsorbent polymers. Other comonomers such as acrylamide and *N* isopropylacrylamide can also be incorporated into the polymer chain. For example, *N*-isopropylacrylamide imparts temperature sensitivity into the superabsorbent polymer. The useful cross-linkers include di-, tri-, or tetrafunctional, and can have mixed types of polymerizable groups such as methacrylate and allyl methacrylate. Mixed types of functional groups provide olefins with varying reactivity toward the main monomer. The mixed-functional cross-linkers can be used to control the incorporation of the cross-links during the polymerization. For example, the gel point of the polymerization can be made at lower conversion of monomers by using a cross-linker that is more reactive than the main monomer. Conversely, the gel point can be delayed to higher conversion of monomers by using a less reactive monomer compared to the main monomer (Mehr *et al*., 2008; Sannino *et al*., 2003).

Variety of monomers, mostly acrylics, is employed to prepare SAPs. Acrylic acid (AA) and its sodium or potassium salts, and acrylamide (AM) are most often used in the industrial production of SAPs. On laboratory scales, however, number of monomers such as methacrylic acid (MAA), methacrylamide (MAM), acrylonitrile (AN), 2-hydroxyethylmethacrylate (HEMA), 2-acrylamido-2- methylpropane sulphonic acid (APMS), N-vinyl pyrrolidone (NVP), vinyl sulphonic acid (VSA) and vinyl acetate (VAc) are also used.

In the modified natural-based SAPs (*i.e.*, hybrid superabsorbents) trunk biopolymers such as cellulose, starch, chitosan, gelatin and some of their possible derivatives *e.g.*, carboxymethyl cellulose (CMC) are also used as the modifying substrate (polysaccharide based SAPs section). *N,N'*-methylene bisacrylamide (MBA) is most often used as a water soluble cross-linking agent. Ethyleneglycole dimethacrylate (EGDMA), 1,1,1-trimethylolpropane triacrylate (TMPTA), and tetraalyloxy ethane (TAOE) are known examples of two-, three- and four-functional cross-linkers, respectively. Potassium persulphate (KPS) and ammonium persulphate (APS) are water soluble thermal initiators used frequently in both solution and inverse-suspension methods of polymerization. Redox pair initiators such as Fe_2+ H_2O_2 (Fenton reagent) and KPS/APS-sodium bi sulphite are also employed particularly in the solution method (Demitri *et al*., 2008).

Properties of super absorbent polymer

The super absorbent polymers are compound that absorb water and swell into many times of their original size and weight. They are lightly cross-linked networks of hydrophilic polymer chains and are used in soil to create a water reserve near the rhizosphere zone (roots) and benefit agriculture (Mehr and Kabiri, 2008; Han *et al*., 2010). The polymers, which have been used for agriculture purpose are safe and non-toxic and will eventually decompose to carbon dioxide, water and ammonia and potassium ions, without any residue (Mikkelsen, 1994; Trenkel, 1997). These also effective on reduction of drought stress effects.

Super water absorbent polymers are found effective to control of soil erosion and water runoff , increasing infiltration capacity along with soil aggregate size (Wallace *et al*., 1986) and reducing irrigation frequency (Taylor *et al*., 1986). They also reducing soil bulk density, increasing water retention (Johnson, 1984), improving the survival of seedlings subjected to drought (Huttermann *et al*., 1999), lengthening shelf-life of pot plants (Gehring *et al*., 1980) and minimizing nutrient losses through leaching under highly leached conditions means increasing nutrient utilization efficiency (Lentz *et al*., 1998).

Functionalized Polymers in Agriculture

Synthetic polymers play an important role in agricultural uses as structural materials for creating a climate beneficial to plant growth e.g. mulches, shelters or green houses; for fumigation and irrigation, in transporting and controlling water distribution. However, the principal requirement in the polymers used in these applications is concerned with their physical properties; such as transmission, stability and permeability or weather ability; as inert materials rather than as active molecules. During the last few years, the science and technology of reactive functionalized polymers have received considerable interest as one of the most exciting areas of polymer chemistry for the production of improved materials (Petruzzelli *et al*., 2000). They have found widespread applications as reactive materials based on the potential advantages of the specific active functional groups and the characteristic properties of the polymeric molecules. Their successful utilizations are quite broad including a variety of fields, such as solid-phase synthesis, biologically active systems and other various technological uses (Ahmed, 1990).

Uses of Super Absorbent Polymers in Agriculture

The ability of SAPs to absorb large volumes of water and retain it within them has many practical applications in agriculture. The saturated hydraulic conductivity of the soil decreases significantly with increase in mixing ratio and swelling property of the SAP. Its swelling reduces the largest pores in the soils, especially in the sandy soils (Koupai *et al*., 2008). The expansion of soil-SAP mixture increases with increase in mixing ratio and swelling property of SAP (Andry *et al*., 2009). Also, the application of SAPs to the soil increases both saturated and residual water content, water holding capacity and available water content. SAPs can be used in the same way as mulch, to help the soil to retain more moisture and also for longer (Buchholz and Graham, 1997).

Amendment of SAPs also affects other properties of soil like infiltration rates, bulk density, soil structure, compaction, soil texture, aggregate stability, crust hardness and evaporation rates. The bulk density of the soil decreases with increase in application rates of SAPs (Bai *et al*., 2010). Application of SAPs to soil also reduces infiltration and thus avoids potential loss to deep percolation. Further, the infiltration reduction produced did not decline with decreasing treated soil layer thickness. The expansion and contraction of SAPs in soil during the cycle of water absorption and evaporation helps to improve air content in the soils, especially in clayey soils. SAPs application in soils greatly reduces irrigation induced erosion and soil water seepage and further increases the uniformity of furrow water applications. Another advantage of amendment of SAP is that it greatly reduces the irrigation frequency particularly in coarse-textured soils. This property could be best utilized for water management practices in arid and semi-arid regions. The SAPs are also biodegradable and further their products do not harm the microbial community present in the soil. SAP amendment increases yield and water use efficiency of plants that is increase in plant biomass. SAP amendment aides plant growth by increase in plant available water, induce faster growth of plants and also prolong survival of plants under water stress and drought conditions (Dorraji, 2010).

Limitations of Super absorbent polymer in agriculture

SAPs are quite fragile and tend to break apart easily thereby losing their water retention property. Further SAPs can also dehydrate rapidly in a matter of hours thus losing their absorbed water (Kim and Nadarajah, 2008). The water absorption of SAPs greatly reduces in the soils as SAPs are under pressure and unable to swell and take in water. The water absorption of SAPs in soils further decreases due to formation of additional crosslink's with certain ions like Ca^{2+} and Al^{3+} present in the soil. The water absorption of the SAP also decreases with increase in salinity of irrigation water The SAPs in soils releases water with increase in temperature and this water could be potentially lost to deep percolation (Andry *et al*., 2009). Further, it could be inferred that the effectiveness of SAP decreased on rewetting and can affect the hydraulic properties of soil only if applied in higher application rates (Geesing and Schmidhalter, 2004). The efficacy of the SAP decreases over a period of time and to compensate for these loses, higher application rates are required .This factor affects the economic value of crops grown on fields amended with SAP.

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