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Antitranspirants in Vegetable Crops

(*Shivali Dhiman, Balbir Singh Dogra, Shiv Pratap Singh, Deepa Sharma and Santosh Kumari)
Dept. of Vegetable Science, Dr Yashwant Singh Parmar University of Horticulture and Forestry, College of Horticulture and Forestry, Neri, Hamirpur, HP-177 001, India
*Corresponding Author's email: shivalidhiman26@gmail.com

Abstract
Water, despite being the most plentiful resource in nature, is also a critical limiting factor in agricultural productivity. Plants lose nearly 99% of their absorbed water through transpiration and evaporation. Transpiration, the release of water vapor from plant surfaces, primarily occurs through structures like stomata, cuticles, and lenticels. As agriculture expands, the importance of water conservation escalates, especially through the chemical control of transpiration using antitranspirants. These substances or chemicals minimize water loss from plant leaves by diminishing the size and frequency of stomatal openings. Antitranspirants are classified based on their action into categories such as stomatal closers, film formers, reflectants, and growth retardants. While they may slightly inhibit growth by affecting gas exchange due to stomatal closure, antitranspirants are valuable in water-deficient soils. Ideally, antitranspirants should be non-toxic, affordable, stable, and effective over time. Research indicates that antitranspirants not only curtail water loss but also bolster physiological traits, disease resistance, crop quality, and yield-related factors in various vegetable crops.

Key words: Antitranspirants, Transpiration, Vegetables

Introduction
Vegetables are typically herbaceous plants or their parts that are consumed in various forms, such as raw, cooked, or even in desserts. They are often referred to as protective foods due to their role in warding off certain diseases. As nutrient-dense components of our diet, vegetables significantly contribute to both personal health and the national economy. The pervasive impact of climate change on various facets of life, including agriculture and food production, is widely recognized. It has left its mark globally, influencing different regions in both positive and negative ways. In India, a subtropical nation, noticeable shifts in weather patterns and rising temperatures are impacting agricultural output. Water, essential for plant growth and development, is becoming increasingly scarce due to climate change, inefficient water management, and the prevalence of pests and diseases, leading to a reduction in crop yields by 20-30%. In these challenging times, antitranspirants emerge as a viable solution to enhance plant resilience under water-scarce conditions and potentially boost vegetable yields.
Water, while being the most plentiful element in nature, also poses a significant constraint in agricultural production. The consumptive use of water in agriculture encompasses three primary components: evaporation, transpiration, and metabolic activities. A staggering 98% of water uptake is expended through transpiration and evaporation, with only 2-3% utilized for metabolic functions.

The presence of water is a critical determinant of plant growth and yield. Insufficient water during the vegetative growth phase can lead to stunted plants, undersized fruits, and premature fruit drop. Remarkably, a mere 5% of absorbed water is allocated for plant growth, while the vast majority—95%—is dissipated via transpiration. Therefore, managing the balance between water availability, plant water needs, and actual water use is crucial, especially during drought conditions where water scarcity becomes the primary challenge for sustaining plant growth.

Transpiration

Transpiration is the evaporation of water from the plant's above-ground parts, primarily through the leaves. This process happens when the stomata are open to allow the exchange of carbon dioxide and oxygen during photosynthesis. It involves the movement of water within the plant and its subsequent release as vapor from parts like leaves, stems, and flowers. While water is vital for plant life, only a minor fraction absorbed by the roots is utilized for growth and metabolism. The vast majority, about 97-99.5%, is dissipated through transpiration and guttation.

Types of transpiration:

Based upon the parts, where transpiration occurs it is of three types viz., Stomatal, cuticular and lenticular transpiration.

Stomatal transpiration: Stomata are minute pores of elliptical shape surrounded by two specialized epidermal cells known as guard cells. They are kidney or bean shape in dicots and dumbel shape in monocots. Transpiration occurs through stomata and is the major form of transpiration, nearly 80-90 % of water is lost from the total amount of transpiration.

Cuticular transpiration: Transpiration takes place through thin cuticle, waxy and shiny layer which is situated on the adaxial part of the leaf. 5-10 % of the water is lost from the total transpirational process.

Lenticular transpiration: Transpiration process takes place through lenticels. Lenticels are the areas in the bark which are filled with loosely arranged cells known as complementary cells, are tiny, permanent openings present on the woody parts of the plants. From this process, very little amount of water (1-5 %) is wasted from the total transpiration.

Fig 1: Different Commercial Product of Some Antitranspirants

Process of transpiration

Transpiration is influenced by the water potential gradient. According to the transpirational pull theory, water ascends from the soil through the roots and up to the leaves. Typically, in fertile soils, there is a higher water potential compared to the atmosphere's lower water potential. This differential drive water movement upward within the plant.

Why transpiration is necessary?

- Creates transpirational pull for transport
- Supplies water for photosynthesis
- Transports minerals from soil to all parts of the plants
- Cools the surface of the leaves and keeps the cells turgid, hence maintains their shape
- Serves to replace water lost through the leaves and remove excess water

Why transpiration is evil?

- Most of the absorbed water is lost without being utilized
- If transpiration rates excced water absorption rates, the leaf cells loose turgor and show wilting
- Deciduous trees shed their leaves during dry spell to avoid transpiration and to protect the plant. Xerophytes show modifications of their leaves and other parts to minimize transpiration process.

Antitranspirants

Antitranspirants are substances that, when applied to plant leaves, help decrease the rate of water loss through transpiration. They work by reducing both the size and number of stomata, thereby conditioning the plants to become more resilient to stress. Spraying these chemicals on plants aims to conserve water by curbing transpiration, which accounts for about 95-98% of a plant's water uptake. Controlling transpiration can assist in maintaining an optimal water balance within the plant. Antitranspirants also prepare plants to withstand stress, offering a strategy to mitigate the impacts of drought stress caused by salinity. The application of foliar sprays is known to significantly improve growth metrics, yield components, and the relative water content of plants.

Ways for reduction of transpiration through antitranspirants

- Some chemicals reduce the absorption rate of solar energy and decrease the leaf temperatures and transpiration rate
- Certain chemicals (wax, latex or plastics) forms thin colourless transparent films which reduces the chances of water vapour to escape from the leaves without affecting the gaseous exchange.
- Certain chemical compounds controls stomatal opening by affecting the guard cells present around the stomatal pore, thus reducing the loss of water vapour from the leaves.

Depending upon the mode or mechanism of action, the antitranspirants are categorized into four types.

Stomatal closing type antitranspirants: Antitranspirants primarily act as agents that induce the closure of stomata when applied to leaf surfaces. Compounds such as the fungicide phenyl mercuric acetate and the herbicide atrazine, when used in low concentrations, serve as antitranspirants by prompting stomatal closure. While they may potentially reduce photosynthesis, it has been observed that phenyl mercuric acetate tends to lower transpiration more significantly than photosynthesis. Abscisic acid (ABA), a non-toxic plant hormone, plays a confirmed role in the closure of stomata, with increased levels of ABA leading to this effect.

E.g.

1. Herbicides like 2, 4-D, phosphon-D, atrazine
2. Fungicides like Phenyl Mercuric Acetate
3. Metabolic inhibitors such as Hydroxyl Sulfonates and Potassium Metabisulphite
4. Growth hormones like ethrel, TIBA and Succinic acid

Film forming type antitranspirants: Film forming antitranspirant form a colourless and thin film on the leaf surface which reduces the transpiration rate by inhibiting the loss of water vapour from the leaf. But they allow carbon dioxide to pass into the leaf through the lower epidermis. Effectiveness of Film forming antitranspirants are up to 10-14 days. Foliage application induces stomatal closure and thus lowers transpirational losses of water from plants. The water proof films on leaf surface reduce the escape of water vapour from transpiring surface. Films on leaves formed from plastic emulsion exhibit a certain degree of selective permeability being more permeable to carbon dioxide and oxygen than to water vapour. E.g.: Hexadecanol, methanol, was emulsions, power oil 1%, Tag 9, S-789 foliate, Plastic films, silicone oils, celite etc.

Reflectance type antitranspirants: These are white reflecting type materials. The reflectant coating may persist for more than 10 days. It reduces the leaf temperature and vapour pressure gradient from leaf to atmosphere by reflecting radiation. Thus decreases the transpiration. Reflecting materials reduce the energy load on the leaf by increasing the albedo. Light reflection for the reflectant coated upper surface of leaves within the canopy may cause an increased light penetration in the canopy. Reflectants may improve the distribution of light within the canopy and may prove beneficial in increasing the photosynthesis. Refelecting compounds do not cause blockage of stomatal pores when applied to the surface of leaves with stomata exclusively on lower surfaces. E.g.: Kaolin, China Clay, Calcium bicarbonate, Lime water. The rate of application of Kaolin is 2-5 per cent and forms a thin white coating film on the leaf.

Growth retardant type antitranspirants: Chemicals which reduce or slow down the shoot growth and increases root growth. Enable the plants to resist drought conditionsthrough the closure of stomata. These are useful for improving the water status of the plant.

Ideal properties of antitranspirants

- Non toxicity
- Reducing transpiration without reduction in photosynthesis to be used on a commercial scale
- Such chemicals should be cheap, stable and long lasting in their effectiveness.
- Antitranspirants form a supplement. Rather than a substitute for, good water management and crop improvement
- Non-permanent damage to stomata mechanism
- Specific effects on guard cells and not to other cells
- Their effect on stomata persists for at least one week.

Benefits of antitranspirants

- High water demanding crops growing in areas of water scarcity.
- Optimized yield levels even under infrequent rainfall conditions.
- Useful for reducing transplanting shock of vegetable seedlings.
- Save several fruits and vegetables from cracking.
- Getting normal sized fruits and vegetables.
- Monitoring/managing drought conditions.
- To prevent the adverse effects of water stress on crop growth can be mitigated by the application of antitranspirants
- Very helpful for farmers having minimum irrigation facilities
- Maintenance of optimum soil moisture for better growth and yield of rabi crops.
- Saving large nurseries when water is in scarce during summer months.

Major constraints

- Maintaining control over microclimatic conditions

- Their effect being varied greatly with environmental factors
- Difficult to cover the entire leaf surface of some crop plants does not receive proper application of the chemical and thus the effectiveness of the chemical may be reduced.
- The lack of awareness and knowledge on the type of nozzles and surfactants to be used.
- The high cost of certain chemicals forbids their use as antitranspirants.
- Some of the chemicals particularly those to be applied through soil are required in relatively high amounts and not thus economical and become a limiting factor in their use.

Precautions to be followed while using antitranspirants

- Spray after rainfall stops.
- Ensure two sprays of antitranspirants at an interval of one week.
- Surfactants should be mixed in spray for effective response.
- Repeat spray of antitranspirants if rains follow after one hour of sprays.

Conclusion

Antitranspirants are beneficial in more ways than just lowering the rate of water loss through transpiration. They play a significant role in improving various aspects of vegetable crops, including physiological processes, growth, disease resistance, and the overall quality and quantity of the yield. For optimal results, it's important to apply antitranspirants at the right growth stage. They are particularly useful in conditions where moisture is scarce, such as in areas with low rainfall or those prone to drought. By mitigating water stress, antitranspirants enhance crop productivity. The foliar application of different types of antitranspirants—such as potassium chloride for stomatal closure, chitosan, folicote, and potassium silicate for film formation, kaolin for reflectance, and growth retardants like CCC—has been shown to improve growth, physiological traits, quality, yield, and related characteristics in vegetable crops.