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Review Article

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The Potential of Anti-transpirants: To Enhance Agriculture Irrigation Efficiency and Chemistry of Agri-foods for Controlling Sugar and Chemistry of Beverages

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Abstract

An increase in the population and the change in diet have put enormous pressure on the Indian soil. Farmers struggle to maintain their level of harvesting, soil degradation, water shortages, declines in biodiversity, and more frequent natural disasters. In addition, agriculture accounts for nearly 14 percent of India's total greenhouse gas emissions. CSA or climate-resilient agriculture can contribute to adapting agricultural systems and attenuating the devastating impact of climate change while producing food and energy sustainably. CSA is an integrated approach to farming, livestock, forests, and fisheries management. It can also solve the interconnected problems of food security and rapid climate change. Smart agricultural practices can help India and the world achieve the following results: increased productivity, improved resilience, reduced emissions, and governmental partnerships, especially in soil and crop management. In order to limit the photosynthetic activity of plants, the use of an anti-transpirant in the field can reduce the accumulation of sugar in berries. This review investigates the role of anti-transpirants in sustainable agriculture, water management, and food safety. The findings indicate that antiperspirants can considerably impair photosynthetic rates, cell conductivity, sugar buildup, and alcohol level in wine. These anti-transpirants can lower crop production costs, increase ripeness, and minimize alcohol intake without altering wine taste characteristics. They can also increase leaf resistance to water vapor dispersion, which reduces plant water stress and influences many agricultural food chemical activities.

Keywords

Anti-transpirants, Climate resilient agriculture, Irrigation, Smart agriculture, Water conservation agriculture

Abbreviation

CSA: Climate smart agriculture; IPCC: Intergovernmental panel on climate change; CO_2: Carbon dioxide; WUE: Water use efficiency; IWRM: Integrated water resource management; PMA: Phenyl mercuric acetate; TIBA: Tri-iodo benzoic acid; ABA: Abscisic acid; SA: Salicylic acid; LWC: Leaf water content; RLWC: Relative leaf water content; MAT: Month after treatment; DAS: Days after sowing; Kg/ha or kg ha^{-1}: Kilogram per hectare

Introduction

Climate change is a challenge for agricultural production and profitability. Small changes in climate patterns can cause large changes in climate events such as rainfall, wind, global warming, etc., causing losses in agriculture and, consequently, economic losses. Agriculture is one of the sectors directly affected by climate change. Various natural processes, such as drought, flood, and global warming, have a significant effect on agricultural activities. Adapting smart tech-

nologies and precision agricultural practices for climate-resistant agriculture are proposed around the world. These precise farming practices integrate agri-workers with related institutions, technologies, financial packages, government. schemes and policies.

The main objective of these practices is to manage water, nutrients, and knowledge so that climate resilience agricultural practices can be developed. The choice of crop varieties should be specific as per the area, the use of technologies and customized tools, crop diversification, the integration of agriculture and weather forecasting tools, and the management of natural resources at the community level are some effective measures for the development of climate-resistant agriculture. Climate change is a reality we face every day. Global surface average temperatures (Figure 1) are largely influenced by CO_2 stocks [1], indicating that the Earth is warming at a rate that has not been observed in 20,000 years. Climate-resisting agriculture itself represents models and practices that are environment-friendly, i.e., avoiding synthetic products as much as possible, improving technology, and improving irrigation services.

The prevalence of drought is almost universal in Africa and South Asia. Countries such as India, Bangladesh, Sri Lanka, and some other Southeast Asian countries depend on rainfall during the storm. Through irrigation systems, water is transported to different corners to avoid floods and to use excess water that can cause flooding in some areas. In an experiment performed by Sadoff et al. [2], observed that countries like East and South Africa, South America, and South and Southeast Asia are mostly running towards loss in gross domestic product because of severe drought (Figure 2). The wine business is looking for ways to minimize alcohol level, which is a source of worry for health reasons. Moderate alcohol concentration can be achieved by canopy control, yeast starters free of saccharomyces, and de-alcoholization. Techniques such as boosting competition among vineyard organs and manipulating photosynthesis conditions can also be employed. Anti-transpirants such as Kaolin and Di-1-p-menthene can lower water-swapping rates while increasing leaf resilience. Kaolin, an inert clay mineral, may regulate heat stress and low temperatures in plant and fruit tissues. Most research has focused on film generation during grape maturity in red grape varietals such as Cabernet Sauvignon, Sangiovese, Barbera, and Aglianico

Irrigation in climate-resilient agriculture

The large cities hit by water scarcity represent around $4.8 trillion from an economic point of view, and climate change significantly impacts water supply and consequently causes economic implications [3]. In 2007/2008, the Barcelona region suffered 1.6 billion euros in economic losses due to drought [4]. As the population grows, the demand for water in the city increases, and to fulfil that, agricultural production also needs to increase [5]. About 40% of the world's largest cities are affected by crop irrigation competition [6]. With continuous climate change, the IWRM demands negotiations on improving water use allocation, WUE, and productivity throughout the different economic sectors in order to combat water scarcity and reduce water competition [7]. Ways to increase urban drought resilience include water conservation, saline water management, purifying water before water transfers, and recovery of water [8-10]. Planting pits - Zai and Half-Mount Techniques Planting pits (like Zai or Tashkent) and Half-Mount structures are water harvesting techniques to preserve water for producing sorghum and corn are found in the Sahel region of West Africa, particularly Mali, Niger, and Burkina Faso, has been successful.

What will happen if we do not focus on smart irrigation management in agriculture as well as daily life water use?

Today's food production techniques involve the use of several synthetic chemicals, preservatives, and fertilizers and are not sustainable processes. The major climatic changes directly affect agricultural sustainability. The main impacts of

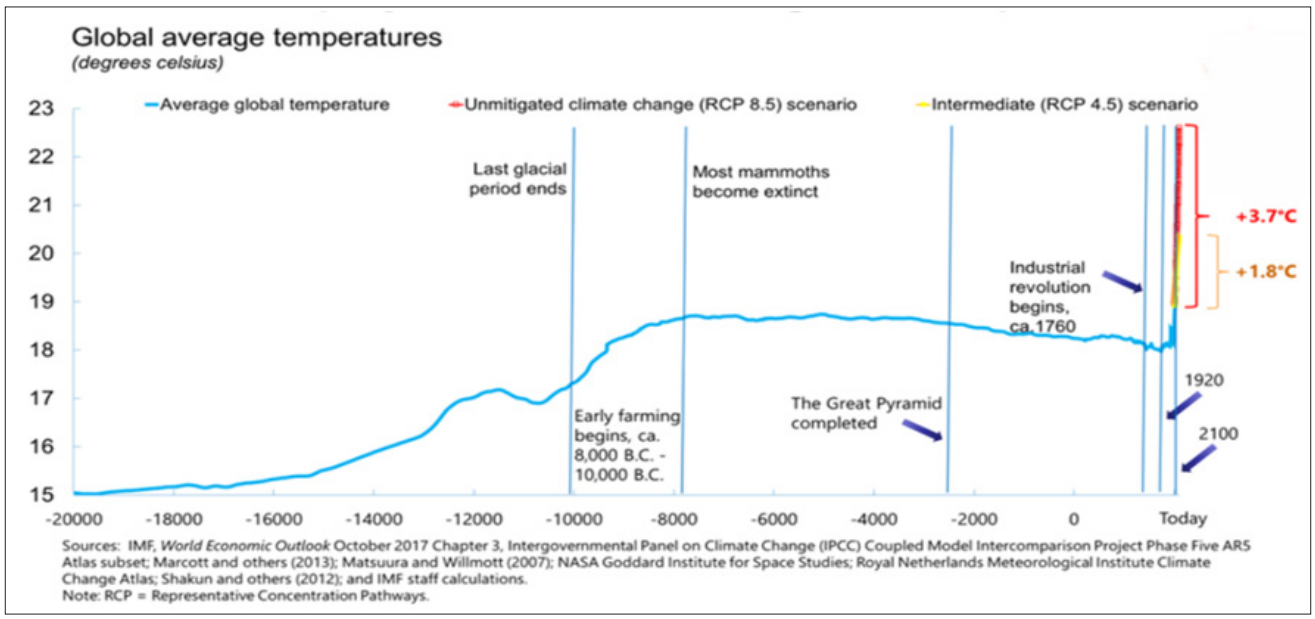

Figure 1: Global average temperatures.

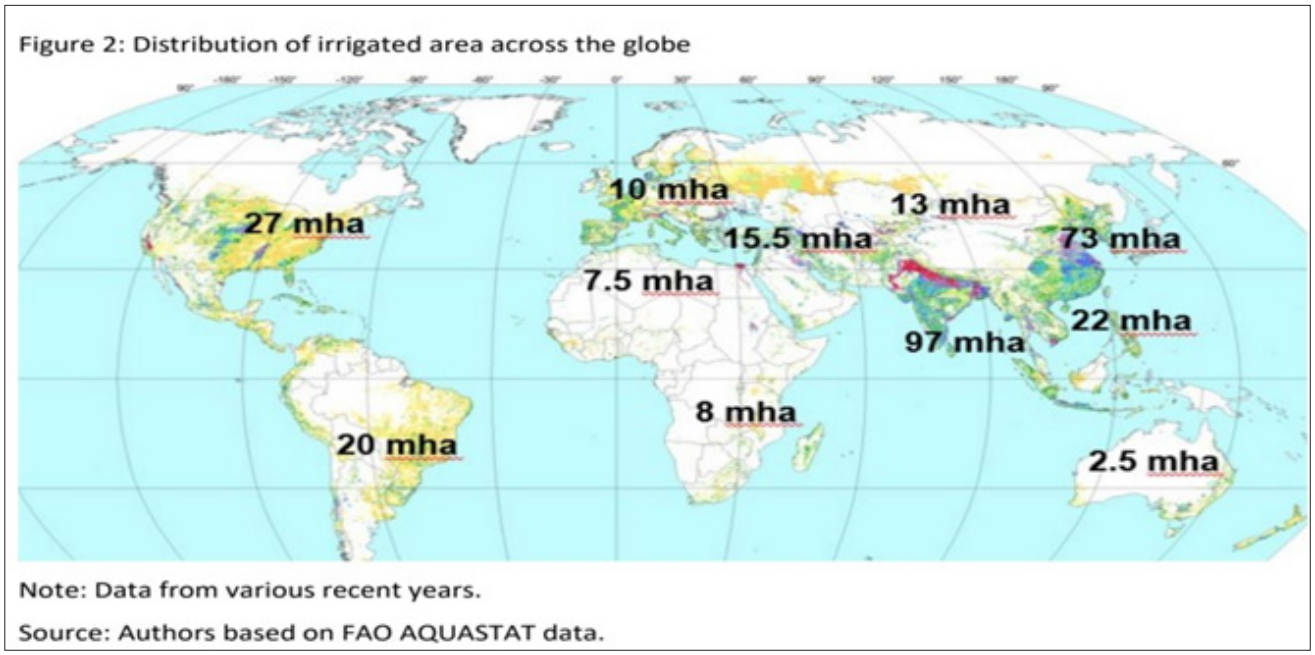

Figure 2: Distribution of irrigated area across the globe.

global warming on agriculture sustainability are as follows:

- Loss of biodiversity in vulnerable environments.
- Loss of soil fertility due to misuse of available water.
- Increased crop failure frequency.
- Increased the effects of parasites and decreased disease resisting ability.
- Unpredictable agricultural conditions in different regions.
- Loss or changes in the distribution and quality of agricultural products.
- Changes in agricultural yields.

Changes in climatic pattern such as rainfall and the arrival and departure of monsoon leads to changes in the locations of different crops. Some geographical areas are better suited to certain crops, while others are experiencing a dry climate that causes a reduction in yields. The economic consequences will have to face for any change in climatic conditions. Resilience is the ability of systems to overcome risks and recover from shocks or adverse effects. When the system is less susceptible to shocks over time, it is resilient and can overcome any adverse situation. Resilience is essential to achieve adaptive capabilities. The adaptation capability includes two dimensions: recovery from shocks and change responses to ensure system flexibility. Overall, CSA has an inclusive, productive, resilient, and low carbon emission capacity [11] that will help to maintain sustainable agriculture and environmental conditions.

Rework on water productivity

There are similar geographical limitations as well as economic limitations, namely the removal of salination properties, problematic water supply, and provision of pure water suitable for agriculture to places far from the main water source. The ineffective use of urban water has an adverse impact on the water originally stored for agricultural production. Irrigation increases food production and productivity and thus increases food availability and access by reducing prices. Irrigation is also essential to the production of other major crops such as sugarcane, corn, fruits and vegetables, and cotton [12]. Increased yields and intensive use of several plant areas reduce the pressure to expand land areas in fragile tropical forests and savannah systems. Without proper irrigation, a significant additional conversion of forests into cropland would be required to reach current food production levels [13].

Changes in crop patterns and the adoption of water-saving technologies such as water-friendly plants in areas that have water, less water-resistant plants in areas that have water scarcity, irrigation management in crop patterns for adequate use of water, the use of anti-transpirant agents, etc., can be applied to reduce water loss. When water is purified and recycled, more value can be generated from the same amount of water. The reuse therefore opens a new door to "water efficiency" and enables water management strategies to achieve efficiency for water use and water savings in larger hydrological systems. The possibility of reallocating water from one agricultural user to another is the only option to support water-efficient agricultural production.

Scope of using anti-transpirants

Under dryland area, reduces the water losses through transpiration. In the areas that are far from irrigation or the irrigation is costly, this helps increase the irrigation interval. In the areas having poor quality of soil water or irrigation water, it helps reduce the uptake of problematic water. To reduce the transplanting shock of nursery plants.

Anti-transpirants increasing WUE

The reduction in productivity is due to several reasons, one of which is water loss. It may be due to dry land conditions, lack of irrigation water, or evaporation. Anti-transpirants are

chemical compounds that reduce the flow rate by minimizing the number and size of stomata and thereby hardening them under stress. They are classified into stomatal closure type (Acetyl salicylic acid). Types of film formation (vapor-gard). Reflective type (kaolin). Growth retardant (cycocel). According to different experts, by maintaining moisture with anti-transpirants, we observed positive results in the quantity and quality of production under low water availability. One of the major achievements of the last decade in anti-transpirant research was to determine the appropriate time to apply the necessary substances associated with the reproductive processes most affected by drought.

Under these frequent droughts, the scenario for the future predicts a reduction in water loss from transpiration, which is required to achieve improved yields of cereals, oil seeds, pulses, fruits, and vegetables. In an experiment by Abdallah et al. [14] it is observed that the application of anti-transpirants kaolin and potassium sulfates on the leaves, increased growth rates, yield and physiological as well as chemical properties such as carbohydrates, enzymes, photosynthetic pigments, and mineral contents of wheat cultivar Gimeza 7. Under water shortage conditions, it was found that anti-transpirants such as puna hydrogel and chitosan together with 60% irrigation were the most effective in increasing growth, reproductive parameters, yield, and yield characteristics, because puna hydrogel can retain a greater amount of moisture, and chitosan was known as an anti-transpirant agent having the capability to decrease the transpiration rate [15]. In an experiment performed by Tamboli and co-scientists [16] observed a higher number and quality of siliquae with the application irrigations at 40 and 75 DAS. The number of siliquae/plants and their length are found better with the application of PMA and kaolin (Figure 3).

Review

Anti-transpirants in drought tolerance of arable crops

Dry regions are defined as areas with less than 750 mm of rainfall per year. It is also defined as an area where the volume of evapotranspiration is higher than the volume of precipitation. It is strange that a place with annual rainfall of 1200 mm during the monsoon season followed by dry winters and summers, causing an evaporation rate of more than 1200 mm, is considered a dry land. Future agriculture and global food production and security will be undermined by severe frequent droughts as well as other abiotic pressures as per IPCC 2018, and the management of rainfall with the application of anti-transpirant substances may be a factor in improving drought. This neglected agricultural technology that can make a significant contribution to reducing drought stress in agriculture production is the use of anti-transpirants. Anti-transpirants are substances used on leaves to reduce the rate of transpiration, thereby improving plant water use potential [17].

Anti-transpirants reduce the transpiration activity which leads to a reduction in productivity. In drought conditions, their actions are more effective. In the case of frequently occurring drought scenarios that are predicted for the future, it will be necessary to reduce water loss due to transpiration in order to improve grain yields. The rapid growth of the world's population will increase the food demand. A detailed study by Kettlewell et al. [18] showed that anti-transpirants should be applied to the plant at its most sensitive stage of drought to avoid any kind of loss. The ability of anti-transpirants to "waterproof" the most crucial stages of crop development by reducing transpiration and improving the WUE during drought periods is proven to be the most effective for the plants to survive in less moisture. It should be noted that anti-transpirants can partially reduce photosynthesis and do not completely stop photosynthesis, while the benefits of reducing carbon assimilation are greater if the product is used to protect the most sensitive stages of drought [19].

Anti-transpirants, a tool for combating water stress

The main characteristics of anti-transpirants are that they are not toxic, they do not permanently damage the stomata mechanism, they affect specific guard cells and no other cells, their effect on stomata persists for a very short period. In a Canola-Must experiment [20] (Figure 4) it was observed that mobileaf and PMA with kaolinite produced more dry matter than non-treated plants. PMA reduces the production of dry matter when soil has high moisture, but not under low moisture soil conditions. Mobileaf that covers the leaves partially may result in a beneficial plant-water balance and an increase in photosynthesis rate because of a reduction in the resistance of mesophyll. The PMA reduced the dry matter production due to the phytotoxic effect, but the PMA combined with kaolinite may enhance the production of dry matter due to the counteractive effects of leaf temperature and the improvement of the plant's water balance. He also observed the highest water consumption efficiency when PMA and kaolinite were

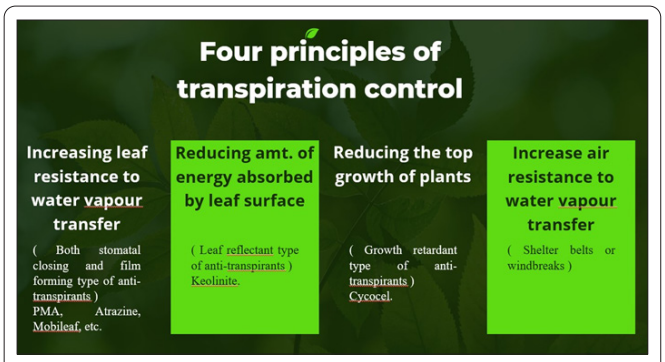

Figure 3: Four principles of transpiration control.

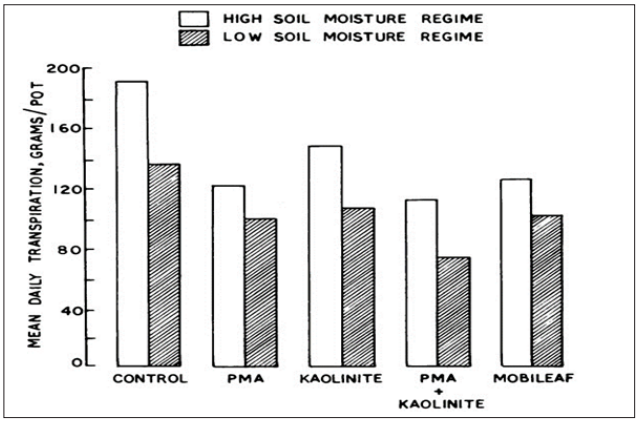

Figure 4: Canola-Must experiment.

used at different soil moisture levels. The day-to-day rate of transpiration of rapeseed plants is reduced to about 25% under low soil humidity regimes.

Film forming type of anti-transpirants

These substances form a thin layer on the leaf surface. They will suppress the loss of water vapor from the leaves. However, they allow CO_2 to enter the leaves [21]. They form colourless film on the surface of leaves, which resists transpiration. The effectiveness of these anti-transpirants lasts 10-14 days. The anti-transpirant vapor guard is di-1-p-methene (also called Pinolene) a polymer. In a research [22], on wheat plants treated with Vapor Gard in dry soil use about 45% less water than non-treated plants. In addition, under dry or less water-available conditions, wheat plants with anti-inflammatory grains result in more grains on each ridge and more yields than controlled plots. Subsequent research has also confirmed this, and the use of vapour gard has significantly increased the yield of wheat (0.7–1.09 kg/ha) in spring under dry climate or drought conditions. These treatments reduce the percentage of losses caused by drought conditions.

Stomatal closing anti-transpirants

Researchers are focusing more on studying the effects of anti-transpirant chitosan on crop plants. Recently in a few years, it has been observed that the number of articles published on the use of anti-transpirant especially stomatal closing types in cereal plants has increased rapidly [23] as chitosan is one of the most widespread and most preferable metabolic stomata closing anti-transpirant. It is a biopolymer that can be obtained from chitin. Being a nontoxic, biodegradable element it is often used as a crop biostimulant [24]. Researchers have shown that chitosan can be used on corn to increase water stress resistance [25]. In wheat, after coating with chitosan, germination rates, grain and dry weight, length, and other physiological activities including root activity are increased considerably [26]. In addition, it was observed that chitosan can eliminate the drought effects in wheat plants, and improve plant growth and development, resulting in an increase in productivity [27]. The useful effects of chitosan increased when mixed with hydrogels [28]. Under a drought environment, the application of SA to barley improves relative water content, nutrient content, and proline accumulation [29]. Wheat (cv HD-2329) also had a positive effect, with SA-treated plants significantly increasing dry weight, leaf chlorophyll, and moisture content [30]. These anti-adjustments improve the closure mechanism of the stomata, thereby reducing the rate of CO_2 diffusion into the leaves. For example:

1. Herbicides that can be used as anti-transpirants are 2,4–D, Phosphon D and Atrazine.
2. Fungicides that act as anti-transpirants are PMA. PMA is a widely used chemical for stomatal closure. It has toxic effects on fruits and vegetables which inhibits phosphorylation and damages the foliage by blocking photosynthesis if used excessively.
3. Hydroxy sulfonates, potassium metabisulphite, etc., are metabolic inhibitors that also act as anti-transpirants.
4. Growth hormones that also work as anti-transpirants are Ethrel, TIBA, succinic acid, etc.

Reflectant type anti-transpirants

These are white materials that form a layer of leaf coating and increase leaf reflection, also known as albedo. They reflect radiation and reduce the temperature of leaves and the vapor pressure gradient from leaves to the environment, which leads to a decrease in the rate of transpiration. Kaolin is a popular anti-transpirant and natural aluminum silicate mineral, in the market its commercial name is Surround. In a research Youssef and Hozayenb [31] conducted studies on Giza 10 corn at different levels of drought stress, when 5% kaolin is applied to 60 and 80 percent evapotranspiration, it has been observed that the physiological and biological quality parameters of the plants and seeds are higher than those of 100% evapotranspiration and non-kaolin corn samples. This shows that kaolin makes plants grow and develop at 40% less water. A study of rice plants conducted with different rates or levels of kaolin applications showed an increase in dry matter and biological yield best in 6% kaolin-treated plants under water deficit conditions [32]. In a study Desoky et al. [33] on wheat plants using 6–10% magnesium carbonate showed the beneficial effects of magnesium antioxidants. They observed improvement in the plant height, chlorophyll a and b content, leaf area, and test weight of wheat under water stress conditions. Other numerous studies have shown that anti-transpirants help reduce drought stress and showed that drought stress can reduce grain yields approximately by 24.25%.

Growth retardant type anti-transpirants

Growth retardant anti-transpirants are chemicals that promote root growth instead of shoot growth. They also induce stomatal closure. Shoot growth produces more leaves and biological matters which will eventually increase the water requirements whereas root growth will help the plants to reach soil depth and get the moisture from the lower soil layers. E.g.: ABA, Cycocel, etc. Cycocel is used for improving the water status of the plant. They delay senescence and help stem reserve utilization, especially during water deficit conditions.

An experiment by Javan et al. [34] showed that kaolin perform better compared to other anti-transpirants. Although in some cases some different results were obtained by some other researchers (Figure 5).

Application of anti-transpirants for improving drought tolerance:

An experiment by Zulkarnaini et al. [35], showed that under Brassinolide optimization, the plant water status was influenced by different levels of anti-transpirant and water stress treatment. The anti-transpirants alone can significantly increase LWC in the third MAT. Different levels of anti-transpirants 0 kg ha^{-1} and 2 kg ha^{-1} respectively increased LWCs during the month-to-month observations, and the anti-transpirant concentration of 2 kg per hectare has increased LWCs above 0 kg ha^{-1} (Figure 6a). In the 1st and 2nd MATs, the water stress treatment alone (Figure 6b) had an important significant effect on the leave's RLWC. Treatment with different

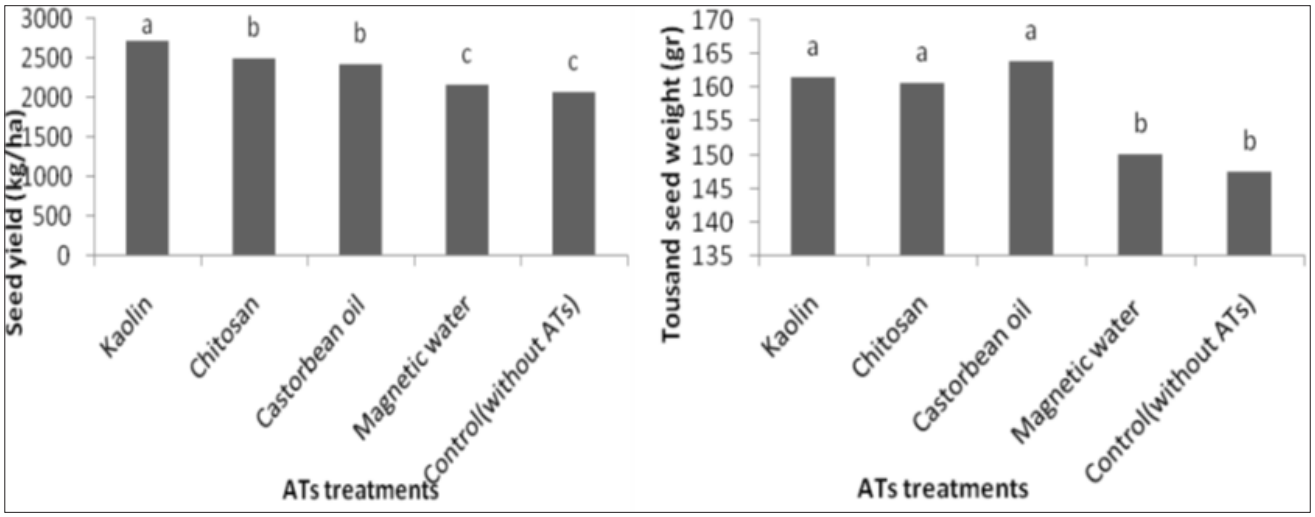

Figure 5: Anti-transpirants treatments.

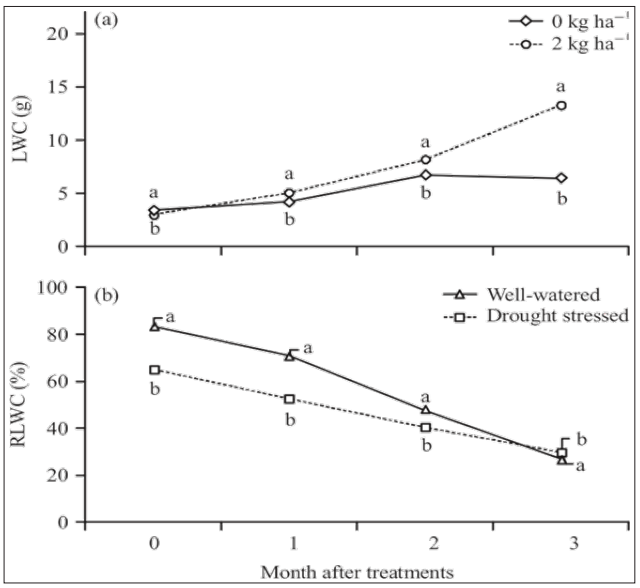

Figure 6: Leaf water status **(a)** Leaf water content and **(b)** Relative leaf water content. [Note: The leaf water content and the relative leaf water content is the main effect of antitranspirant and water stress under Brassinolide optimization respectively].

levels of anti-transpirants at 0 kg ha^{-1} and 2 kg ha^{-1} decreased the RLWC in every month's observation, while treatment with well-watered conditions increased the RLWC compared to drought-stressed treatments. As per the work it has been observed that anti-transpirants have reduced the harmful effects of drought to a certain extent by adjusting the enzyme antioxidants activity and the characteristics of the exchange of gas, which has contributed to maintaining plant growth. In other words, anti-transpirant agents can be said to help plants grow by utilizing less water.

Conclusion

Evaluations of the climate change impacts on the environment mainly on agriculture and its related soil and water, crop production, and water demand are essential measures to improve its resilience to harmful impacts. In the climate change scenario, the smart and sustainable use of natural resources requires rational use to preserve these resources for future generations. In the area of water and other resources, the paper reviewed several procedures for preserving water without jeopardizing crop loss, such as irrigation management and the use of anti-transpirants to conserve water and improve water use efficiency. Furthermore, the findings indicate that intelligent and precision agricultural practices are the only means of achieving sustainable agriculture, and also can be achieved by the ways, discussed in this review. In summary, the strategies play a vital role in enhancing food security. The application of di-1-p-menthene anti-transpirant during veraison resulted in decreased stomatal conductance, net photosynthesis, and water use efficiency index (WUEi), thus proving to be an effective method for reducing sugar content in grapes intended for producing moderate alcohol wines. Importantly, this treatment did not alter the chemical composition or aroma profile of both grapes and resulting wines, thereby preserving the unique sensory characteristics of varietal wines.

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None.

Conflict of Interest

There is no conflict of interest.

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