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WATER USE EFFICIENCY – OPTIMIZING THE WATER USE EFFICIENCY OF FIELD CROPS THROUGH STRATEGIES

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Abstract:

Enhancement of water use efficiency (WUE) in crops is crucial for sustainable agriculture, particularly in water-limited areas. Various methods are the reason behind the enhancement of WUE. The use of drought-tolerant or short-duration crop varieties enables improved growth under limited water. Drip and sprinkler irrigation provide water to the root zone directly, minimizing loss. Mulching helps in the conservation of soil water and reduction of evaporation. Balanced application of the fertilizer for nutrient management facilitates growth of healthy roots, enabling greater water uptake. Sowing at proper times and scheduling irrigation according to crop requirements and weather forecasting also improves water efficiency. Techniques like rainwater harvesting and soil health maintenance through the addition of organic matter also contribute. Weed suppression enables more water to be supplied to the crops. Monitoring devices like soil moisture sensors prevent over- and under-irrigation. By implementing these methods, farmers can produce more crops per drop of water, ensuring improved production and conservation of water.

Key words: Osmoregulation, Water use efficiency, Crop yield, Evapotranspiration, Water management, Smart Irrigation systems.

Introduction:

When the population increases, there is increased demand for food and animal feed. But climate change is making it more difficult to produce crops. To have more foods, fibers, and feeds, we must produce more crops with the same amount of land, so more water is used. But water is limited. They discovered that by the end of this century, restricted freshwater may cause 20–60 million hectares of irrigated lands to rely solely on rain. Water management in agriculture overlaps numerous disciplines in fields such as hydrology, engineering, soil, and plant sciences. But each discipline exists independently, producing knowledge gaps. It is also difficult to quantify how each component of the water system is efficient compared to the whole, especially in scaling from small farms to large fields. Water is recycled through runoff, drainage, or even wastewater, so it is difficult to trace. Quantifying each component of the water cycle is challenging but is crucial to improvement. Finally, most farmers are not motivated to conserve water, particularly when water is inexpensive or conserved water is used by others and not by them.

Water-use efficiency (WUE) is an indicator of how efficiently crops utilize water to grow and yield crops. It is the ratio of water consumed to crop yield. More water consumed decreases WUE, but reduces crop yield with sufficient water supply. High WUE crops develop normally and stress slowly under drought conditions, though. WUE is distinct from drought tolerance or transpiration efficiency. Researchers use enhanced irrigation, nutrient application, and stress-tolerant crop varieties to increase WUE. This is important for the future of agriculture, especially with increasing drought and heat from global climate change.

To solve this issue, we need to have smart ways of utilizing water for farming. When plants are deprived of water, they grow slower since essential body functions are compromised. We need to see which parts of the plant are more affected so that we can protect or promote them. Roots, for example, behave differently when it is dry. In rice, roots grow deeper into dry soil to reach water whereas roots in flooded soil stay near the surface and do not grow as long. Additionally, small root hairs help plants take in water during dryness. Therefore, we need to know how plants especially roots and leaves react to dryness so that we can utilize water more wisely and yield more crops with fewer waters.

Water use efficiency:

Water Use Efficiency (WUE) is the productivity of a crop in utilizing water to produce and yield. It is the proportion of crop produced per unit of water absorbed. Irrigation by improved techniques like drip or sprinkler irrigation, growth of drought-resistant crops, fertilization, and soil health enhance WUE. Mulching, sowing time, and weeding also increase the use of water by crops. Rainwater harvesting and storage in rainfed areas increase water use. With these smart agriculture practices, we can save water and yet produce more food, which is needed during water scarcity times.All the water taken up by a crop went only into forming the part that we harvest, only 1 mm of water could produce record yields. But in the real world, crops need much more water due to other uses some unavoidable, others avoidable. That is why there needs to be a clear definition of water-use efficiency (WUE). WUE has been defined differently at different times and used in so many different fields like agronomy, hydrology, and plant science. WUE may be different based on whether the focus is on transport of water in the environment or on plant use for growth.

1. Hydrological Approach:

In hydrology, WUE is quantified as the ratio of available water such as rainfall, irrigation water, and soil water that actually gets used by crops for growth. This includes water transpired (used by plants through leaves) and sometimes water evaporating from soils or from the plant surface.A functional definition, especially for irrigation systems, is given by Bos and Nugteren (1974). They quantified WUE as a ratio of irrigation water that contributes to the water content in the root zone of the crop. This means WUE can be quantified as a ratio: water effectively used by crops to total water supplied. This value always falls between 0 and 1 (or 0% and 100%).

In irrigation systems, WUE tends to be divided into components, which are:

Water conveyance efficiency – how much water reaches the farm through canals or pipelines.

Field application efficiency – actually how much of the water finds its way into the crop root zone. Engineers can examine those numbers and see where water is being wasted and how to make the system better.

This hydrologic WUE is useful under semi-arid or arid climatic conditions where there is limited water. It is mostly studied by water managers and irrigation system engineers interested in water-saving technology.

2. Physiological Perspective:

WUE is a different term used in plant physiology. Here, it is the quantity of plant biomass or crop yield produced per unit of water lost by the crop. This water loss typically is for transpiration, where plants release water vapor through leaves, and soil and plant surface evaporation. All these are collectively called evapotranspiration. However, scientists have proposed that to call this an "efficiency" is not accurate. This is because evaporation and transpiration are physical processes and do not directly lead to plant growth, although they are connected. Due to this, the term "transpiration ratio (RT)" is used. This is called the quantity of water lost in comparison to how much dry matter (e.g., stems, leaves, and grain) the plant produces.

When both canopy and ground evaporation are also considered, it is referred to as "evapotranspiration ratio (RET)". These are usually given as grams of dry matter produced per gram of water taken up (RT or RET usually ranges between 100-1000 g/g). RET is occasionally given in field experiments per hectare and in units of water taken up.

2.1. Plant canopy area:

Crop water use is regulated by canopy size and shape mainly. A closed canopy shades the soil, reducing temperature and water loss through evaporation. Early canopy cover saves soil water quickly. Plants have different canopy types—some with many stems, others with more or larger leaves. Smaller canopies with deeper roots use less water early, which is reserved for grain formation later. "Stay-green" types of traits save yield under drought by controlling canopy size. Canopy and root trait control together can induce improved crop development with less water use, especially in arid areas.

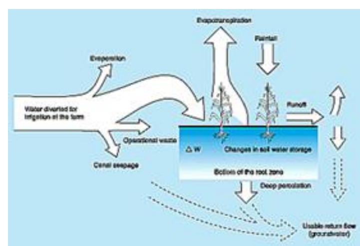

Figure 1: Water balance in field

2.2. Leaf anatomy:

Leaves are crucial for plant growth, water consumption, and food production via photosynthesis. The size, shape, orientation, and surface characteristics of leaves influence water usage. Upright leaves utilize water more effectively than declining leaves. The quantity of leaves and opening of tiny pores (stomata) regulate water loss and carbon dioxide intake. Thicker leaves and additional leaf hairs can assist plants in conserving water, particularly during drought. Other crops also modify leaf shape or close stomata on hot afternoons to conserve water. Understanding and modification of these leaf characteristics can assist in breeding crops that thrive on fewer water.

2.3. Osmoregulation:

Plants regulate water intake in dry weather with the help of osmoregulation. Water is carried by xylem from the soil, and water is stored and released by phloem as needed. Vacuoles and some compounds like proline help regulate water pressure and cell protection in the plant cells. A plant hormone ABA helps in the closure of very small leaf pores (stomata) to save water, though it slows down growth. Essential minerals like potassium help too, though plants will grow at a slower pace. Even if plants grow at a slow pace, regulation of water intake keeps them alive in dry areas. Osmoregulation keeps crops healthy and saves water during dry spells.

2.4. Crop yield:

Water Use Efficiency (WUE) and yield are generally linked, but higher WUE is not always with higher yield. WUE is crop output divided by water consumed. Drought may make WUE seem higher because of less water loss, but crop output is lower. Studies show that complete irrigation results in higher output, but limited water can increase WUE but reduce output. Nutrients and growth stages also affect this balance. Certain crops store water under stress, but this is not always with higher output. Efficient use of water with less loss, and not just WUE, results in better output under drought.

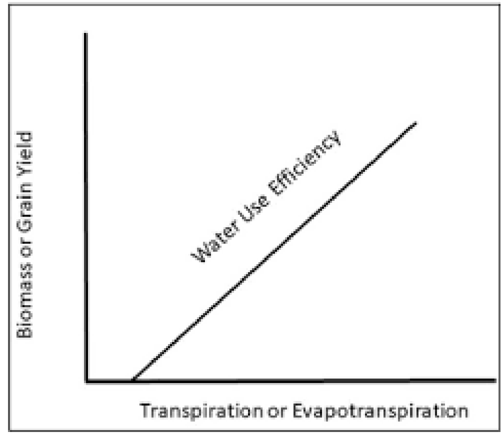

Figure 2: Relationship between crop yield and evapotranspiration

3. Nutrient management:

Farmers have a lot of issues when there is a lack of water. This restricts the amount of food they can produce. One way to make plants grow well when there is little water is to control the way we provide them with nutrients such as fertilizers. This can cause plants to conserve water and grow well even in times of drought.

Plants require certain things to remain healthy and grow well. These are basic nutrients like nitrogen, phosphorus, and potassium, and small quantities of others such as zinc, boron, and iron. When plants receive a good balance of these nutrients, they can develop deeper roots, retain more water in leaves, and withstand dry climates.

Through intelligent watering practices like drip irrigation and straw or plastic sheet mulching, water can also be saved. Terracing and contour planting can stop water from running off and keep the soil healthy. All the nutrients have a different function. Nitrogen, for example, encourages leaf growth and photosynthesis. Potassium helps the plant to control the loss of water. Magnesium is needed for green leaf color, which helps the plant to make food. Micronutrients like zinc and boron help with small but important activities in plant growth and health. Overall, giving the right nutrients at the right time helps plants get healthier, use more water efficiently, and grow more during water shortages. This makes farming more efficient and saves valuable water resources.

Conclusion:

In short, Water Use Efficiency is a most important term in water management and crop science but differently defined in each discipline. The hydrological perspective is concerned with how water is supplied and utilized over fields and the physiological perspective is concerned with how plants utilize water to grow. Both perspectives are important for enhancing agriculture under water-limited conditions and for maintaining food production. With less water with climate change, farmers must produce more food with less water. Farmers can do this by applying improved farming practices and utilizing crops with good roots and small leaves. Scheduling the planting season, weeding, fertilizing, and conserving water at the farm can result in higher crop yield.

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