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Tiny Crystals, Big Impact: How Super Absorbent Polymers Are Transforming Agriculture in a Water-Scarce World

Yashmeen Sharma

Introduction:

Water is critical for agriculture. As a result, freshwater will continue to be one of the largest concerns affecting food security around the world. Agriculture uses approximately 70 percent of the world's freshwater that is withdrawn. Droughts and changes in precipitation patterns caused by climate change have made it increasingly difficult to provide sufficient soil moisture for crop production. Because of their ability to absorb hundreds of times their weight in water, super absorbent polymers (SAPs) are proving to be very useful in modern agriculture. These amazing materials are revolutionizing how farmers manage soil moisture, decrease irrigation needs and improve crop yields. As a result, SAPs are being more widely used as practical, scientifically supported options for sustainable agriculture in regions prone to drought such as North America and many arid areas of Africa and Asia.

What Are Super Absorbent Polymers?

Superabsorbent polymers, or SAPs, are cross-linked, hydrophilic polymers that can retain an extremely large volume of water relative to their own weight. When dry (similar to the size of sand) and exposed to water, a SAP becomes a soft gel. For example, one gram of SAP can hold as much as 200 g of water. Most SAPs are made from polyacrylamide, polyacrylic acid, and copolymers of starch. In response to increasing environmentally related issues, researchers have begun creating biodegradable and biologically based SAPs using cellulose, chitosan, and/or lignin. The three main commercial forms of these materials are: granules, powders, and composite hydrogels, which are best suited for different types of soils, crops, and methods of application.

How It Works in Soil:

The SAP process is composed of two main factors: the osmosis principle and the unique cross-linking of the polymer. When added to soil, SAP granules will absorb any moisture (from either irrigation or rainfall) and create a hydrogel that can store this water for the future. When soil becomes dry, water will be released back to the soil as the difference in osmotic pressure between the gel and the dry

Yashmeen Sharma

MSc Soil Science, Lovely Professional University

soil brings the two into equilibrium over time. As this cycle of absorption and release continues, the ability of the polymer to retain water diminishes substantially. In sandy loam soils, the addition of SAP (> 0.1-0.3% of soil mass) has resulted in a significant increase in volumetric water content and a decrease in irrigation frequency. The incorporation of SAPs into soil has also resulted in a number of additional benefits, including improved soil aggregation and aeration in heavy clay soils, reduction in bulk density in compacted soils, all of which enhance conditions for microorganisms and root growth.

Benefits for Agriculture:

Reduced Irrigation Water Usage: One of the primary benefits of using SAP's (Soil Amendments with Particles) is the reduced use of irrigation water. SAP's retain moisture in the root zone reducing the amount of water lost through deep percolation and evaporation, while slowly releasing moisture back into the surrounding area. Multiple studies have indicated that crops treated with SAP's require 30 - 50% less irrigation water than non-treated crops while yielding an equivalent level of production.

Improved Germination and Establishment of Seedlings: The establishment of seedlings is one of the most critical and water dependent points in the life cycle of a crop. Seedlings are typically more susceptible to mortality (death) due to moisture stress at this point. SAPs, applied within close proximity to the seed zone, can reduce seedling mortality in seeds planted in sandy soils or under rain-fed conditions by ensuring that there is moisture available to seedling plants during the germination process. Studies have indicated that seed germination rates and the vigour of seedlings germinated under dryland conditions was significantly improved when seeded with SAPs.

Improved Nutrient Efficiency: Through the absorption and subsequent slow release of soluble nutrients such as K+, NH4+ and NO3- from decomposing organic matter in soil, SAP's can reduce the leaching loss of nutrients and enhance nutrient efficiency for crop production. Crop yields have been substantiated in studies showing that nitrogen fertilizer leaching was reduced as much as 40% when using SAP's without negatively impacting crop performance.

Water Conservation and Environmental Benefits:

Agricultural water conservation needs to happen now; Soil-absorbent polymers (SAPs) help improve soil infiltration (increasing surface runoff), reduce water loss through evaporation from the surface of the soil, and reduce deep drainage by storing water within the root zone of plants. For example, if drip irrigation is being used with SAPs applied around the emitters (drainage holes), less frequent watering will occur because the effective wet zone will increase, thus reducing water consumption while continuing to produce healthy crops. In addition, SAPs contribute to water conservation by enhancing the biological activity in the soil because the moisture conditions are more stable and therefore support the development of fungi (mycorrhizal), bacteria (nitrogen-fixing), and worms (earthworms). SAPs can also be used to rehabilitate and restore vegetation on degraded soil surfaces and improve the soil's ability to hold water back to eroded or degraded sites.

Effect on Crop Growth and Yield:

Scientific evidence shows that SAP contributes to improved yields for agricultural crops. A meta-analysis of 45 studies on 20 crops has shown that SAP resulted in increased biomass of shoot and root, a larger leaf area index and increased photosynthetic rates, especially under water-stressed conditions. The results of studies have shown that applying SAP under deficit irrigation has increased the yield of grain crops such as wheat, corn, and sorghum by 15-35 percent as compared to control plants that did not receive SAP. Similar increases in productivity and improvements in quality of fruit produced by horticultural crops such as tomatoes, peppers and cucumbers have also been documented. Most importantly, plants grown in soil containing SAP, when compared to control plants grown in similar soil conditions without SAP, maintained higher leaf water content, lower leaf temperature and better stomatal conductance during periods of severe drought stress, which is indicative of enhanced resistance to extreme weather events.

Conclusion:

Super absorbent polymers provide a unique connection between modern agricultural needs and cutting-edge polymer technology. Super absorbent polymers address multiple interconnected problems by improving the ability of soils to hold moisture, decreasing the amount of water needed for irrigation, improving the efficiency of nutrients, and increasing crop yield when faced with stress.