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ADVANTAGES OF DRIP IRRIGATION IN SOYBEAN (*GLYCINE MAX*) AND SORGHUM (*SORGHUM BICOLOR*) CULTIVATION: AGRONOMIC, PHYSIOLOGICAL, AND ENVIRONMENTAL PERSPECTIVES.

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Abstract.
Efficient water management has become a critical issue in global crop production, particularly in semi-arid regions where water scarcity limits yields and threatens agricultural sustainability. Soybean and sorghum—both economically and strategically important crops—exhibit different physiological responses to moisture stress but share a high sensitivity to irrigation timing. Drip irrigation offers precise water delivery to the rhizosphere, reducing losses and improving water productivity. This review synthesizes published field research and introduces a conceptual optimization framework aimed at enhancing production efficiency in soybean and sorghum. The evidence indicates that drip irrigation increases water-use efficiency, improves nutrient uptake, stabilizes yields under drought conditions, and reduces environmental externalities. The proposed conceptual model highlights opportunities for integrating sensor-driven irrigation with fertigation to further enhance production outcomes.

Key words: Drip irrigation, Water-use efficiency, Soybean (Glycine max), Sorghum (Sorghum bicolor), Fertigation, Root-zone moisture, Sustainable agriculture, Crop productivity.

Introduction. Water scarcity has been identified as one of the principal constraints to agricultural productivity in the 21st century. As major staple and industrial crops, soybean (*Glycine max*) and sorghum (*Sorghum bicolor*) are increasingly cultivated in regions experiencing irregular rainfall, growing evapotranspiration demand, and rising temperatures. Conventional irrigation systems such as furrow or flood irrigation, although widely used, result in substantial water losses through evaporation, runoff, and deep percolation. These inefficiencies are particularly problematic in coarse-textured soils common in dryland agriculture.

Martinez et al. (2018) report that drip irrigation can increase water-use efficiency in soybean by up to 30%. According to Singh and Prakash (2020), fertigation significantly enhances nutrient uptake, while Dlamini (2021) notes that drip irrigation promotes stronger root system development in sorghum. Drip irrigation, characterized by low-pressure localized water delivery, has been shown to maintain soil moisture within an optimal range, thereby supporting more stable physiological activity in crops [1]. While soybean often suffers from moisture fluctuations during flowering and pod formation, sorghum demonstrates superior drought tolerance yet still benefits significantly from controlled water supply during booting and grain filling stages [2]. Therefore, analyzing the advantages of drip irrigation in these two crops provides valuable insights for improving productivity under water-limited conditions.

Water-use efficiency (WUE). Numerous studies indicate that drip irrigation markedly increases WUE due to its ability to minimize non-productive water losses. In soybean systems, maintaining soil moisture near field capacity during reproductive stages directly influences seed set and pod retention. Experiments conducted in semi-arid environments show that drip-irrigated soybean requires 25–40% less water while achieving equal or higher yields compared with surface irrigation. Sorghum, although inherently water-efficient, responds positively to drip irrigation particularly during the critical growth stages. Enhanced WUE results from sustained stomatal activity, reduced transpiration stress, and improved canopy temperature regulation. The spatial placement of water in the root zone allows sorghum to maintain metabolic activity even under evaporative demand, mitigating yield penalties commonly observed in overhead irrigation systems [3].

Root system architecture and soil moisture distribution. Drip irrigation creates a vertical and lateral moisture gradient that encourages deeper root exploration. Soybean roots extend more uniformly, with increased fine-root density, leading to improved nutrient absorption. This is particularly important for nitrogen and potassium, both of which are vital for seed development.

In sorghum, drip irrigation promotes a robust fibrous root network capable of extracting water more efficiently from subsoil layers [4]. Enhanced rooting depth directly correlates with higher grain weight and improved plant resilience during transient drought periods.

Maintenance of photosynthetic activity. Controlled water delivery under drip irrigation results in a more stable physiological environment. Soybean leaves exhibit higher chlorophyll concentrations and reduced midday depression of photosynthesis. Similarly, sorghum plants maintain more favorable leaf water potential, which supports sustained carbon assimilation throughout the grain-filling period.

Yield performance and biomass production. Aggregated data from multiple field studies indicate the following trends:

Soybean: Drip irrigation often increases seed yield by 15–30% due to improved pod retention and seed weight.

Sorghum: Yield gains range from 12–25%, driven by enhanced panicle size and grain uniformity.

In addition to grain yield, total aboveground biomass increases substantially under drip irrigation, offering added value in systems where sorghum stover is harvested for livestock feed or bioenergy.

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Improved nutrient-use efficiency (NUE). One of the primary agronomic benefits of drip irrigation is the integration of fertigation—delivering nutrients directly with irrigation water. This technique provides several advantages:

- More uniform nutrient distribution in the wetted root zone,
- Reduced nitrogen volatilization and leaching
- Enhanced phosphorus availability due to sustained moisture levels
- Increased potassium mobility in the soil

Soybean, being a legume, also benefits from the improved conditions for rhizobial nitrogen fixation. Sorghum, with its deep root system, is able to capitalize on consistent nutrient availability throughout the season [8].

Controlled nutrient delivery allows producers to reduce total fertilizer inputs by approximately 20–35% without compromising yield. This creates economic savings and mitigates environmental risks associated with nutrient runoff.

Weed and disease suppression. Drip irrigation limits water application to crop rows only, leaving inter-row spaces relatively dry. This suppression of weed germination reduces herbicide requirements and manual weeding costs. Additionally, because foliage remains dry, incidences of leaf diseases—such as soybean rust—are significantly reduced.

Minimal soil disturbance and controlled salinity movement help preserve soil structure. In regions with saline irrigation water, drip systems prevent salt accumulation in the root zone by pushing salts away from the wetting front.

Cost-effectiveness. Although the initial investment in drip irrigation equipment is relatively high, long-term economic returns are generally favorable due to:

- Reduced water consumption
- Lower fertilizer rates
- Higher and more stable yields
- Reduced labor costs

For perennial or high-value crops, these returns are even greater, but research indicates the system is increasingly viable for field crops like soybean and sorghum as well.

7. Conclusion

Drip irrigation represents a highly efficient and scientifically validated water management strategy for soybean and sorghum production. Its benefits extend beyond water conservation to encompass improved physiological stability, enhanced nutrient-use efficiency, reduced pest and disease pressure, and increased economic returns. The integration of sensor-based irrigation, fertigation, and predictive

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modeling offers significant potential for further yield improvements [10]. As global water scarcity intensifies, drip irrigation will play a central role in ensuring sustainable crop production and food security.

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