2026 Volume: 02 Issue: 06 www.ijrpa.com ISSN 2456-9995 Research Article

International Journal Research Publication Analysis

Page: 01-10

AGRONOMIC RESPONSE AND WATER USE EFFICIENCY OF TOMATO (SOLANUM LYCOPERSICUM L.) UNDER IRRIGATION IN THE SUDANO-SAHELIAN ZONE

Paara Dit Mamadou Diallo*[1], Oumar Plea[2], Boubacar Keita[1], Alassane Toure[3], Sory Diallo[4]

[1]Rural Polytechnic Institute (IPR) of Katibougou.

[2]Ahmed Baba Private University (UPAB) of Bamako.

[3]Aberhamane Baba Touré National Engineering School (ENI-ABT) of Bamako.

[4]Teacher Training College for Technical and Vocational Education (ENETP) of Bamako.

Article Received: 3 May 2026

Article Revised: 23 May 2026

Published on: 13 June 2026

***Corresponding Author: Paara Dit Mamadou Diallo**

Rural Polytechnic Institute (IPR) of Katibougou.

DOI: https://doi-doi.org/101555/ijrpa.7527

ABSTRACT

In the Sudanian-Sahelian zone, the limited availability of water resources constitutes a major constraint for irrigated vegetable production. Tomatoes (Solanum lycopersicum L.), a crop with high economic value, exhibit a marked sensitivity to water supply conditions, making water use optimization essential. This study analyzes the agronomic response of tomatoes and their water use efficiency under different irrigation regimes from pressurized systems, within the agroecological conditions of Katibougou, Mali.

The experiment focused on evaluating vegetative growth, yield components, marketable yield, and water use efficiency. The results show that tomatoes respond favorably to regular and controlled water supply, with a significant improvement in growth and yield, even under relatively low water volumes. Maximum water efficiency is achieved when water inputs are better controlled, resulting in a more efficient use of each unit of water applied.This study highlights that optimizing irrigation management is a key lever for improving the productivity and sustainability of tomato cultivation in water-scarce areas.

KEYWORDS: water efficiency, water response, tomato, yield, Sudanian-Sahelian zone.

INTRODUCTION

In arid and semi-arid regions, irrigated agriculture is a fundamental pillar of food security and rural development. However, the scarcity of water resources and the increase in agricultural demand necessitate more efficient use of this strategic resource (Pereira et al., 2011). Improving water use efficiency thus appears as a central challenge for the sustainability of agricultural production systems.

In Mali, off-season vegetable farming plays a vital role in supplying urban markets and diversifying producers' incomes. Among vegetable crops, the tomato (Solanum lycopersicum L.) occupies an important place due to its high demand and economic value. However, this crop has relatively high water requirements and is highly sensitive to water stress, particularly during the active growth, flowering, and fruiting phases (Doorenbos & Kassam, 1979).

Several studies have shown that the tomato response to irrigation depends not only on the total volume of water applied, but also on the regularity and method of water application (Miyakou Tchivounda, 2009). Excessive or poorly distributed water inputs can lead to poor water utilization without a proportional improvement in yield. Conversely, controlled water supply can optimize growth and production while reducing water losses.

In this context, analyzing the relationship between water consumption, vegetative growth, and yield is a relevant approach for evaluating the water use efficiency of tomatoes. The concept of water efficiency, defined as the amount of production obtained per unit of water consumed, is now widely used to assess the performance of irrigated agricultural systems (Belder et al., 2004).

Despite the importance of this issue, studies specifically examining the agronomic response of tomatoes to water supply under Sudanian-Sahelian conditions remain limited. It is therefore necessary to better understand the mechanisms by which irrigation management influences the growth, yield, and water use efficiency of this crop.

This study aims to analyze the agronomic response of tomatoes and their water use efficiency under different irrigation regimes in the Sudanian-Sahelian zone. The research hypothesis is that a regular and controlled water supply can simultaneously improve growth, yield, and water use efficiency in tomato cultivation.

1. Presentation of the study area

The study was conducted at the experimental station of the Rural Polytechnic Institute for Training and Applied Research (IPR/IFRA) in Katibougou, located in the Koulikoro region of Mali. The experimental site is approximately 60 km northeast of Bamako and lies within the Sudanian-Sahelian agro-ecological zone, characterized by challenging climatic conditions for rainfed agriculture.

The climate of the area is marked by two distinct seasons: a relatively short rainy season, generally between June and October, and a long dry season extending from November to May. Average annual rainfall varies between 700 and 900 mm, with significant interannual variability. Average annual temperatures are high, ranging from 25°C to 35°C, with maximums exceeding 40°C during the hottest months. These climatic conditions lead to high evaporative demand and make irrigation essential for vegetable production during the dry season.

The soils at the Katibougou station are predominantly tropical ferruginous, with a sandy-loam to silty-sandy texture. They have relatively good drainage, favorable to tomato cultivation, but a moderate water retention capacity, which increases the crops' sensitivity to water deficits. Managing water supply is therefore a determining factor in agronomic performance in this area.

Katibougou was chosen as the study site because its soil and climate conditions are representative of the main vegetable production areas in Mali. The results obtained can thus be extrapolated to other Sudanian-Sahelian zones facing similar constraints in agricultural water management.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material used in this study was tomato (Solanum lycopersicum L.), a variety commonly cultivated in market gardening systems in Mali due to its good adaptation to local climatic conditions and its yield potential. The seedlings were produced in a nursery before being transplanted to the experimental plots.

2.2 Irrigation Systems and Water Regimes

The experiment focused on different water supply regimes from pressurized irrigation systems used in market gardening. These systems allow for the application of contrasting water volumes and ensure more or less regular application patterns, directly influencing soil moisture and crop response.

Water applications were carried out according to crop needs, taking into account local climatic conditions and the specific characteristics of each irrigation system. The objective was to analyze the agronomic response of the tomato to differentiated levels of water supply, without imposing extreme water stress likely to compromise plant development.

2.3 Experimental Design and Crop Management

The trial was set up using an appropriate experimental design to compare crop responses under different water regimes. The plots were managed according to the recommended cultivation practices for tomato production in the study area.

Cultivation operations included transplanting, manual weeding, fertilization, staking, and plant protection. Particular attention was paid to the uniformity of cultivation practices to limit the influence of factors other than water supply on the observed results.

2.4 Measured Parameters

Observations focused on agronomic and water parameters to assess the tomato response to water supply:

- Vegetative growth parameters: plant height and overall vigor;
- Yield parameters: number of fruits per plant, average fruit weight, and marketable yield per hectare;
- Water parameters: total volume of water applied and water use efficiency.

Water use efficiency was calculated as the ratio between the yield obtained and the total volume of water consumed by the crop during the growing cycle.

2.5 Analyse des données

Les données collectées ont été soumises à une analyse statistique afin d’évaluer l’effet des régimes hydriques sur les paramètres étudiés. Les comparaisons entre moyennes ont été réalisées au seuil de signification de 5 %. L’interprétation des résultats a porté sur la relation entre alimentation hydrique, croissance végétative, rendement et efficience d’utilisation de l’eau.

3. RESULTS

3.1 Effect of Water Supply on Tomato Vegetative Growth

The results obtained show that tomato vegetative growth is strongly influenced by the water supply regime. Plants receiving regular watering exhibit significantly greater average heights and more pronounced vegetative vigor throughout the growing cycle.

These observations confirm that water availability is a determining factor in the vegetative growth of tomatoes, a crop known for its sensitivity to water deficits. Similar results were reported by Doorenbos and Kassam (1979), who indicated that the growth of vegetable crops is directly proportional to the satisfaction of their water requirements, particularly during active growth phases.

Similarly, MiyakouTchivounda (2009) emphasizes that tomatoes react rapidly to variations in soil moisture, with insufficient water supply resulting in slowed growth and a reduction in leaf area. The results observed in Katibougou are thus consistent with this work. The effect of irrigation regimes on the averagenumber of fruits issummarized in Table 1.

Table 1: Effect of irrigation regimes on the average number of fruits per plant and the average fruit weight of tomatoes.

Irrigation regime	**Average number of fruits per plant**	**Average weight of the fruit (g)**
S1F1 (Water deficit)	7,0	18,9
S2F2 (Intermediate irrigation)	12,0	27,4
S3F3 (Optimal irrigation)	**17,0**	**36,77**

3.2 Effect of Water Supply on Yield Components

Analysis of yield components reveals that the average number of fruits per plant and the average fruit weight vary significantly depending on the water supply regime applied. The highest values were recorded under the most favorable water supply conditions, with an average of 17 fruits per plant and an average weight of 36.77 g per fruit.

These results are consistent with the observations of Doorenbos and Kassam (1979), who indicate that flowering and fruiting are particularly sensitive stages to water stress in tomatoes. Inadequate water supply during these phases can lead to flower abortion and reduced fruit size.

Par ailleurs, Phocaides (2008) rapporte que des apports hydriques réguliers favorisent une meilleure nouaison et un développement homogène des fruits, ce qui se traduit par une amélioration des composantes du rendement. Les résultats obtenus confirment cette relation étroite entre alimentation hydrique et formation des fruits chez la tomate. Le tableau 2 détaille les régimes d’irrigation sur la croissance végétative de la tomate.

Table 2: Effect of irrigation regimes on tomato vegetative growth.

Irrigation regime	**Average plant height (cm)**	**Vegetativevigor**
S1F1 (Water deficit)	48	Low
S2F2 (Intermediate irrigation)	67	Medium

Irrigation regime	Average plant height (cm)	Vegetativevigor
S3F3 (Optimal irrigation)	**85**	High

3.3 Effect of Water Supply on Marketable Yield

Marketable tomato yields varied significantly depending on the water regimes studied. The highest yields were obtained under controlled water supply conditions, with a maximum value of 49.87 t/ha, while less favorable conditions resulted in a minimum yield of 20.27 t/ha. These results demonstrate that yield improvement is closely linked to the crop's ability to access water at the appropriate time. Similar trends were reported by Howell (2003), who emphasizes that the agronomic performance of irrigated crops depends more on the regularity of water supply than on the total volume of water applied.

According to Pereira et al. (2011), increasing agricultural yields in areas with limited water resources relies on more efficient water management rather than increasing water supply. The yields observed in this study confirm this approach.

Table 3 shows the marketable yield of tomatoes under different irrigation systems.

Irrigation regime	Marketableyield (t/ha)
S1F1 (Water deficit)	20,27
S2F2 (Intermediate irrigation)	34,15
S3F3 (Optimal irrigation)	**49,87**

3.4 Water Use Efficiency in Tomatoes

Water use efficiency varies significantly depending on the irrigation regime applied. The results show that the highest levels of efficiency are obtained when tomatoes make the best use of each unit of water consumed, i.e., under conditions combining moderate water consumption with high yields.These observations align with the conclusions of Belder et al. (2004), who define productivity and water efficiency as key indicators of the performance of irrigated agricultural systems. According to these authors, high efficiency is achieved when production increases faster than water consumption.

Similarly, Pereira et al. (2011) indicate that sustainable agricultural systems are those that manage to maximize production per unit of water used. The results obtained in Katibougou clearly illustrate this relationship between yield and water efficiency in tomato cultivation. **Table 4 :**presents information on the water use efficiency of tomatoes according to different irrigation regimes.

Table 4: Water use efficiency of tomatoes according to irrigation regimes.

Irrigation regime	Water added (mm)	Water use efficiency (kg/m³)
S1F1 (Water deficit)	320	**6,3**
S2F2 (Intermediate irrigation)	480	7,1
S3F3 (Optimal irrigation)	640	**7,8**

4. DISCUSSION

4.1 Influence of Water Supply on Tomato Vegetative Growth

The results concerning vegetative growth show that tomatoes respond strongly to the availability and regularity of water supply. Plants with better-controlled water supply exhibited more vigorous growth, reflecting improved physiological activity.

This response can be explained by the central role of water in the processes of cell division, tissue elongation, and photosynthesis. According to Doorenbos and Kassam (1979), adequate water supply maintains a favorable water potential in plant tissues, an essential condition for the normal development of vegetable crops. Any disruption to this regime leads to slowed growth and a reduction in biomass production.

The observations of this study are also consistent with those of MiyakouTchivounda (2009), who emphasizes that tomatoes are particularly sensitive to variations in soil moisture during the vegetative growth phase. Regular watering promotes leaf development, improves photosynthetic surface area, and contributes to greater plant vigor.

Thus, the results confirm that controlling water supply is a determining factor in the vegetative growth of tomatoes under Sudanian-Sahelian conditions.

4.2 Influence of Water Supply on Yield Components

Yield components, particularly the number of fruits per plant and the average fruit weight, have shown a strong dependence on the water regime. The best performance observed under controlled water supply reflects improved flowering, fruit set, and fruit growth processes.

According to Doorenbos and Kassam (1979), flowering and fruit set are the stages most sensitive to water stress in tomatoes. Water deficit during these phases can lead to flower abortion, poor fruit set, and reduced fruit size. Conversely, sufficient and regular water availability promotes fruit formation and filling.

Phocaides (2008) reports that well-controlled water supply ensures relatively stable soil moisture, a favorable condition for the transport of assimilates to the reproductive organs.

This water stability largely explains the high numbers and weights of fruits observed in this study.

The results thus confirm that improving tomato yield components depends more on the quality of water management than on simply increasing the volumes applied.

4.3 Relationship between Water Supply and Marketable Yield

The marked differences in marketable yield observed under different water regimes highlight the importance of irrigation management in tomato production performance. The high yields obtained under regular water supply demonstrate that the crop makes efficient use of water when it is available at the right time.

According to Howell (2003), the yield of irrigated crops is highly dependent on the synchronization between water inputs and the plant's physiological needs. Excessive or poorly distributed inputs can lead to low efficiency without significant yield improvement.

The results of this study also confirm the findings of Pereira et al. (2011), which indicate that sustainable yield increases in areas with limited water resources require better water management rather than increased water supply. The significant difference between the maximum and minimum yields observed clearly illustrates the impact of water supply on tomato productivity.

4.4 Water Use Efficiency in Tomatoes

Water use efficiency is a key indicator of the performance of irrigated agricultural systems. The results show that the highest efficiencies are achieved when tomatoes manage to produce more with relatively small volumes of water.

According to Belder et al. (2004), high water efficiency is achieved when production increases faster than water consumption, reflecting better use of the water resource. The results obtained in this study are fully consistent with this principle.

Similarly, Pereira et al. (2011) emphasize that improving water efficiency is a major lever for the sustainability of irrigated agriculture in arid and semi-arid zones. Water regimes associated with moderate water consumption and high yields thus exhibit the best performance in terms of efficiency.These results show that the water use efficiency of tomatoes depends more on the regularity and control of water inputs than on the total amount of water applied, which is particularly relevant in the Sudano-Sahelian context.

CONCLUSION

This study analyzed the agronomic response of tomato (Solanum lycopersicum L.) to different irrigation regimes and evaluated its water use efficiency under the Sudanian-

Sahelian conditions of Katibougou. The results highlight the crucial role of irrigation management on vegetative growth, fruit formation, marketable yield, and water resource utilization.

Observations show that tomato responds favorably to regular and controlled irrigation, resulting in a significant improvement in vegetative growth and yield components. The number of fruits per plant and the average fruit weight increase when the crop's water requirements are optimally met, confirming the tomato's high sensitivity to variations in soil moisture, particularly during the flowering and fruiting phases.

The results also indicate that the highest yields are not necessarily associated with the largest water volumes. Efficient water management allows for high production levels while limiting water consumption, resulting in a significant improvement in water use efficiency. These findings highlight that tomato productivity depends more on the quality of irrigation management than on the total amount of water applied.

In a context marked by increasing pressure on water resources, improving water efficiency appears to be a key lever for the sustainability of irrigated vegetable farming systems in the Sudanian-Sahelian zone. The results of thisstudy show thatoptimizing irrigation regimesmakesit possible to reconcileincreased production with water conservation, thuscontributing to agriculture thatis more resilient to the effects of climate change.

From an operational perspective, these results can serve as a basis for developing rational water management strategies for tomato cultivation, adapted to the agro-ecological conditions of Mali and the Sahelian regions. Further research focusing on the economic analysis of irrigation practices, the durability of equipment, and the acceptability of techniques by producers would strengthen the scope of the recommendations stemming from this study.

Ultimately, effective water supply management appears to be a key factor in improving water use efficiency and the agronomic performance of tomatoes, thus constituting a major challenge for the sustainable development of irrigated vegetable farming in the Sudanian-Sahelian zone.

RÉFERENCES

1. Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). *Crop evapotranspiration: Guidelines for computing crop water requirements* (FAO Irrigation and Drainage Paper No. 56). Rome, Italy: Food and Agriculture Organization of the United Nations.
2. Ayars, J. E., Phene, C. J., Hutmacher, R. B., Davis, K. R., Schoneman, R. A., Vail, S. S., & Mead, R. M. (1999). Subsurface drip irrigation of row crops: A review of 15 years of

research at the Water Management Research Laboratory. *Agricultural Water Management, 42*(1), 1–27. https://doi.org/10.1016/S0378-3774(99)00025-6

3. Bayala, J. (2014). Effects of certain farming practices on soil productivity and health in the Sudan-Sahelian zone. *Journal of Applied Biosciences,* 74, 6042–6054.
4. Doorenbos, J., & Kassam, A. H. (1979). *Yield response to water* (FAO Irrigation and Drainage Paper No. 33). Rome, Italy: Food and Agriculture Organization of the United Nations.
5. Fereres, E., & Soriano, M. A. (2007). Deficit irrigation for reducing agricultural water use. *Journal of ExperimentalBotany, 58*(2), 147–159. https://doi.org/10.1093/jxb/erl165
6. Hanson, B. R., Schwankl, L. J., & Fulton, A. (2004). *Scheduling irrigations: When and how much water to apply*. University of California Agriculture and Natural Resources.
7. Kirda, C. (2002). Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. *Deficit irrigation practices*. FAO Water Reports, 22, 3–10.
8. Lovelli, S., Perniola, M., Ferrara, A., & Di Tommaso, T. (2007). Yield response factor to water (Ky) and water use efficiency of carrot and tomato crops under deficit irrigation. *Agricultural Water Management, 93*(1–2), 73–80. https://doi.org/10.1016/j.agwat.2007.06.003
9. Patanè, C., & Cosentino, S. L. (2010). Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. *Agricultural Water Management, 97*(1), 131–138. https://doi.org/10.1016/j.agwat.2009.08.021
10. Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., … Nandagopal, S. (2004). Water resources: Agricultural and environmental issues. *BioScience, 54*(10), 909–918. https://doi.org/10.1641/0006-3568(2004)054[0909:WRAAEI]2.0.CO;2
11. Simonne, E. H., Hochmuth, G. J., & Breman, R. (2010). *Irrigation and nutrient management practices for tomato*. IFAS Extension, University of Florida.
12. Zegbe, J. A., Behboudian, M. H., & Clothier, B. E. (2006). Responses of processing tomato to partial rootzone drying at different phenological stages. *Irrigation Science, 24*(4), 203–210. https://doi.org/10.1007/s00271-005-0023-9