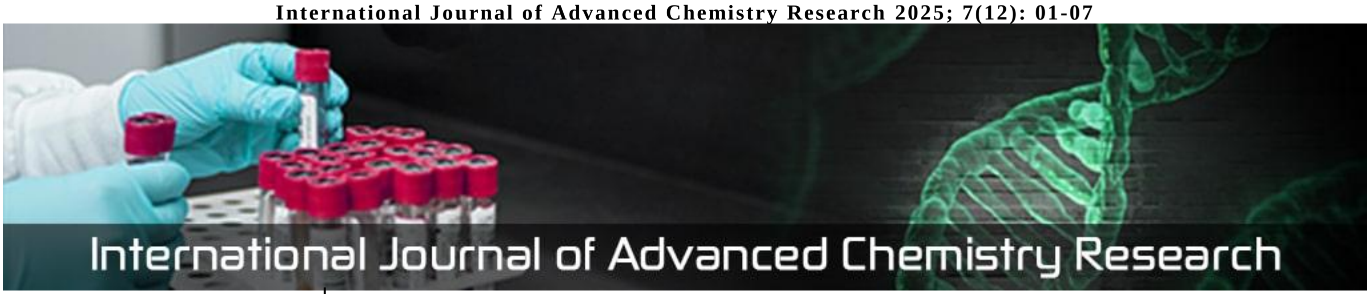

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Effect of mulching and irrigation methods on soil moisture, growth, and yield of tomato (*Solanum lycopersicum* L.)

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Abstract
The study was conducted to evaluate the influence of different mulching materials and irrigation methods on the growth, soil properties, and yield of tomato (*Solanum lycopersicum* L.). The experiment was laid out over a 200 m² area (16 m × 12.5 m) and comprised four treatments: plastic polythene mulch with drip irrigation (A), coconut coir mulch with drip irrigation (S), drip irrigation without mulch (M), and control (K) under conventional furrow irrigation. The drip irrigation system was designed and installed to deliver uniform water distribution, while crop water requirements were estimated using the FAO CROPWAT 9.0 model based on climatic and soil parameters. Results indicated that drip irrigation, particularly when combined with mulching, significantly improved soil moisture retention and reduced bulk density compared to conventional irrigation. The highest tomato yield (2.018 t/ha) was obtained under plastic mulch with drip irrigation (A), followed by coconut coir mulch with drip irrigation (1.412 t/ha), drip without mulch (1.405 t/ha), and the lowest yield (0.873 t/ha) under control conditions. The improvement in yield under mulched drip treatments was attributed to better soil moisture conservation, enhanced nutrient availability, and reduced evaporation losses. Overall, the study concludes that the combination of plastic mulch and drip irrigation is the most efficient water management practice for improving soil conditions and maximizing tomato yield under the agro-climatic conditions of Surampalem.

Keywords: Cropwat, mulch, tomato, irrigation, drip, and yield

1. Introduction

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae. The tomato is the edible, often red, berry of the plant *Solanum lycopersicum*, commonly known as the tomato plant. The species originated in western South America and Central America. The Nahuatl (the language of the Aztecs) word *tomatl* gave rise to the Spanish word *tomate*, from which the English word *tomato* is derived. Its domestication and use as food likely began with the indigenous peoples of Mexico. The Aztecs used tomatoes extensively in their cooking at the time of the Spanish conquest. After their encounter with the Aztecs, the Spanish brought the plant to Europe. From there, the tomato was introduced to other parts of the European-colonized world during the 16th century. Numerous varieties of tomato are widely cultivated in temperate climates across the globe, and the use of greenhouses enables tomato production throughout all seasons. Tomato plants typically grow to a height of 1-3 meters (3-10 feet).

India is among the top producers of tomato, with an annual production of about 18.4 million tonnes (approximately 12% of global production, FAO 2016), which rose to 19.74 million tonnes (FAO 2018). However, China ranks first in tomato production, producing 56.3 million tonnes, about 32% of the global output. In 2018, world production of tomatoes reached 182 million tonnes, with China contributing 34%, followed by India, the United States, and Turkey (FAO). Water is life, as neither plants nor animals can survive without it. Water is crucial for ensuring food security, sustaining industrial production, and conserving biodiversity. However, in recent decades, water has become an increasingly scarce resource globally. More than 300 million people in 26 countries currently face water shortages, and estimates suggest this number could rise to 66 countries, affecting two-thirds of the global population (Farhad and Jayashree, 2010) [10].

In India, about 60-70% of the economy depends on agriculture, and increasing food production for the growing population is a pressing challenge. Allocating water between agricultural and industrial sectors has become critical. India possesses only 2.4% of the world's land area and 4% of its freshwater resources. In agriculture, traditional irrigation methods are widely practiced, leading to significant water wastage. Such practices also increase cultivation costs, cause nutrient leaching, pollute groundwater, raise soil salinity, and promote pests and diseases. Therefore, it is essential to improve water use efficiency through the adoption of drip irrigation systems. Drip irrigation not only reduces water use but also lowers production costs.

Mulch refers to a layer of material applied to the soil surface to conserve moisture, improve soil fertility and health, suppress weed growth, and enhance the visual appeal of the area. At the start of the growing season, mulch helps warm the soil and retain heat overnight, enabling early seeding and transplanting and encouraging faster growth. As the season progresses, mulch stabilizes soil temperature and moisture and reduces weed growth. Materials commonly used as mulch include coir, wood chips, paper, stones, plastic sheets, and paddy straw.

Coconut fibre or coir, a natural byproduct of coconut processing, comes from the outer husk of the coconut. In recent years, coir has gained popularity among gardeners as mulch, soil amendment, and potting mix ingredient. The benefits of coir mulch include renewability, high water-retention capacity, and improved soil fertility. Coir also enhances soil aeration and can store water up to six times its volume, making it widely used in organic farming.

2. Description of study site: The study was conducted in the agricultural research farm of Aditya University, which is situated near Surampalem, Andhra Pradesh. The average annual temperature of the site is approximately 27.3 °C. The region receives moderate to high precipitation, with an average annual rainfall of about 980 mm.

2.1 Selection of experimental field

The experiment was conducted in the agricultural research field of Aditya University during the period of January to March 2024, covering an area of about 200 m² (16 m × 12.5 m) to analyse the growth and yield characteristics of tomato crops grown under various mulching materials with and without drip irrigation, and also under control conditions. The research farm was located at approximately 17°05'36.9" N latitude and 82°04'04.1" E longitude, at an altitude of about 27-30 m above mean sea level. The soil of the experimental site was sandy loam in texture, and the source of irrigation was a borewell located on the campus.

2.2 Land preparation

After clearing the field, primary tillage operations were performed using a tractor-drawn cultivator to initially loosen the soil and remove existing weeds. After five days, the land was tilled again with a tractor-mounted rotavator to thoroughly mix and level the soil. On 10th January 2024, the field was properly marked and prepared for seedbed formation and subsequent transplanting of tomato seedlings.

2.3 Layout and design of experimental field

The seedbed was prepared manually with shovels, covering a total dimension of
16 m × 12.5 m for transplanting. The total area of the experimental field was approximately 200 m², divided into four plots, namely: i. A (Plastic polythene mulch with drip), ii. S (Coconut coir mulch with drip), iii. M (Without mulch with drip), and iv. K (Control without mulch and without drip).

The seedlings were transplanted with a row-to-row spacing of 50 cm and plant-to-plant spacing of 35 cm. The details of the experimental field layout are given below:

Table 1: Experimental Plot for various treatments with their specifications

S. No	Treatment	Method of irrigation	Size of Plot (m × m)	Area (m²)
1	Plastic polythene mulch with drip	Drip irrigation	16 × 3	48
2	Coconut coir mulch with drip	Drip irrigation	16 × 3	48
3	Without mulch with drip	Drip irrigation	16 × 3	48
4	Control (without mulch and without drip)	Furrow irrigation	16 × 3	48

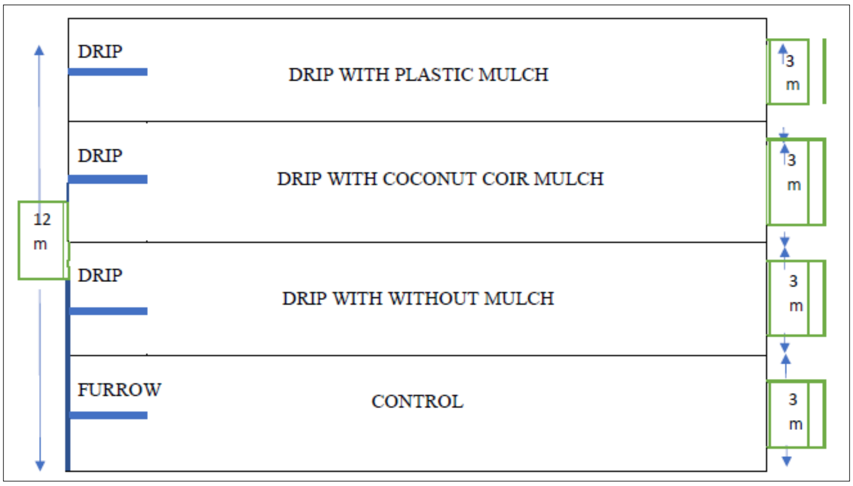

Fig 1: Experimental Plot with specifications

3. Drip Irrigation System
Drip irrigation is an efficient irrigation method that conserves water and fertilizer by delivering water slowly and directly to the plant roots, either onto the soil surface or directly into the root zone, through a network of pipes and emitters. For this study, the drip irrigation system was installed in an experimental field of approximately 16 × 12.5 m² area. One lateral line was provided for each row of crops, maintaining a spacing of 50 cm between crop rows and 50 cm between laterals to ensure uniform coverage.

The main components of the drip irrigation system included the main line, sub-main line, lateral pipes, drippers, pressure gauge, end plugs, and control valves. The drippers were placed at 35 cm spacing, and water was supplied through a 50 mm diameter PVC main pipe and 12 mm LLDPE lateral pipes.

The system was tested by maintaining a fixed operating pressure at the pump house and measuring the dripper discharge using the volumetric method. The emission uniformity, manufacturing variation, and system efficiency were calculated to assess the overall performance of the system.

3.1 Components of the drip irrigation system
1. **Main Pipe:** A PVC pipe of 50 mm diameter (Class 2, 4 kg/cm²) was used to convey water from the source to the experimental site through the sub-mains.
2. **Sub-Main Pipe:** A PVC pipe of 32 mm diameter (Class 3, 6 kg/cm²) was used as the sub-main to distribute water from the main line to the laterals.
3. **Lateral Pipe:** An LLDPE pipe of 12 mm diameter, with drippers spaced at 35 cm, was used to deliver water directly to the plant root zone from the sub-main pipes. Each lateral contained approximately 40 drippers.
4. **Pump:** An existing electric pump with a 2.5 hp capacity was used to operate the drip irrigation system efficiently.
5. **Screen Filter:** The screen filter used consisted of a stainless-steel screen of 100 mesh (0.15 mm) enclosed in a PVC body. Filtration was achieved by forcing the water through the screen. Specifications included: head control system with screen filter, ball valves, flush-out, end caps, plugs, start connectors, jointers, rubber grommets, pressure gauge, air release valve, and other accessories.

For the present study, the methods of irrigation selected were

1. **Drip irrigation** for plots A, S, and M
2. **Farmer's practice** (hosepipe spray) for plot K.

In the drip irrigation system, 12 mm laterals with dripper-to-dripper spacing of 35 cm were used. The drip system was operated using a 2.5 hp motor with water drawn from a borewell located at the site.

3.2 Application of mulch: The total area of the experimental plot was approximately 200 m² (16 m × 12.5 m). The objective of the study was to identify a suitable mulching material for enhancing the growth and yield of tomato (indigenous variety). Two types of mulches Coconut coir and polyethylene sheets were applied at an average depth of 2-3 inches as a surface layer shortly after planting, along with a no-mulch condition as control.

3.3 Transplantation of Tomato: The selected tomato seedlings were transplanted maintaining a plant-to-plant distance of 35 cm and row-to-row distance of 50 cm, with 50 cm lateral spacing for all treatments, ensuring the same plant population per unit area across all plots. The seedlings were carefully placed in the prepared soil as per the designed spacing, at a depth of not more than 4 cm, to ensure proper establishment of roots.

3.4 Crop Water Requirement: For the present study, the crop water requirement for tomato was calculated using CROPWAT 9.0, which utilizes the FAO Penman-Monteith method for estimating reference crop evapotranspiration (ETo). These estimates were used to determine the irrigation water requirements and develop an appropriate irrigation schedule for the crop. CROPWAT 9.0 calculates the irrigation water needs of the cropping pattern for various growth stages of the crop throughout the season, taking into account local climatic, soil, and crop data.

4. Results and Discussion
4.1 Crop water requirement of Tomato
The crop water requirement (CWR) for tomato crop was estimated using CROPWAT 8.0 based on the climate data such as rainfall data, maximum and minimum temperatures, relative humidity, sunshine hours and wind speed including crop data and soil data. The crop water requirement for the tomato crop are presented in Plate 4.1 and it was found that crop water requirement for tomato crop during experimental period (January 1st week to April 1stweek) as during the crop growing period, rainfall is not considered as experiment was conducted in summer season.

4.2 Irrigation Scheduling: Irrigation schedules were prepared for Tomato crop based on the climate data, crop data, cropping pattern data and soil data using CROPWAT 8.0 model consider there is no rainfall during the crop period and furnished in Table 4.1. It was found that 83.3 mm of water was required for development stage, 87.2 mm of water was required for middle stage and 99.3 mm of water was required for late stage. Time of operation of the drip irrigation system for all the drip treatments with and without plastic mulch (A, S and M) was calculated and operated the drip system daily as per the irrigation schedule and for conventional method of irrigation without mulch K (control), 8mm depth of water is applied at daily throughout the crop period with the help of pipe.

Table 4.1: Irrigation schedule for the tomato crop for all drip treatments

Month	Decade	Stage	Irrigation requirement (mm/day)	CWR (mm/day)	Time of operation per day for drip system (min)
Jan	1	Init	3.6	1.19	10.71
Jan	2	Init	12.1	1.21	10.89
Jan	3	Deve	17.3	1.57	14.13
Feb	1	Deve	24.5	2.45	22.05

Feb	2	Mid	33.0	3.30	29.70
Feb	3	Mid	29.5	3.68	33.12
Mar	1	Mid	39.4	3.94	35.46
Mar	2	Late	41.8	4.18	37.62
Mar	3	Late	42.5	3.87	34.83
April	1	Late	33.3	3.33	29.97
April	2	Late	6.1	3.04	27.36

4.3 Bulk density: The soil samples were collected before and after experimentation and analysed for bulk density by core cutter method from all the treatments. The average values of bulk density for 26 initial stage of the crop and at harvesting stage of the crop are observed that the slight increase in the bulk density in the drip plots comparatively from control i.e. traditional method of cultivation. Maximum increase in bulk density was observed in the traditional cultivation due to the soil compaction with the over application of water. In drip irrigation experimental plots having the less increment in bulk density and there is no much change due to the effect of plastic mulching.

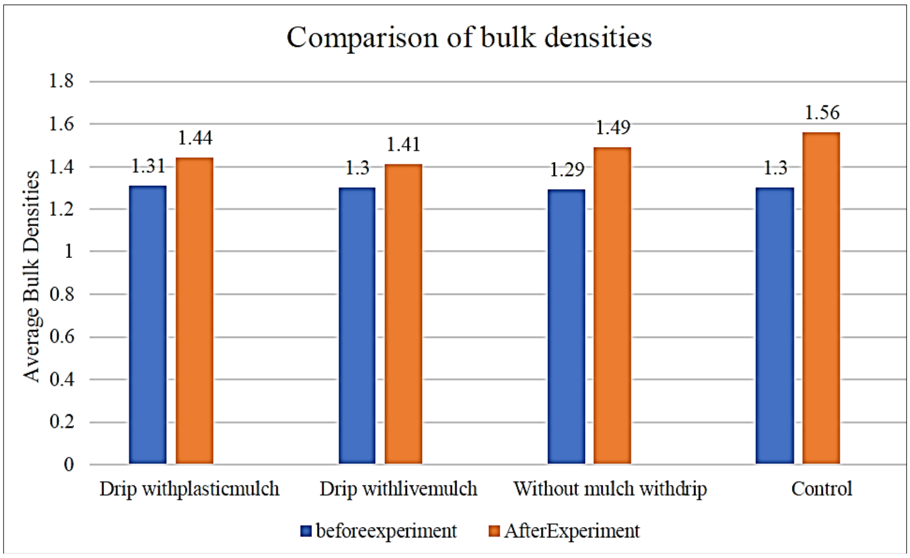

Fig 4.1: Comparison of bulk densities of soil before and after experimentation

4.4 Soil Moisture Content: The soil samples were collected at a depth of 15 cm at different stages of crop growing period and analysed for determination of moisture content present in soil using oven drying method. The results revealed that there is significance difference in soil moisture content between the different treatments with mulching and without mulching. Mulching can greatly inhibit soil water evaporation and significantly improve the soil water status. The mulched plots had higher soil moisture content during the experimental period. Soil moisture in mulched plots is not only higher, but is also more stable during the entire vegetation period, an important factor for crops.

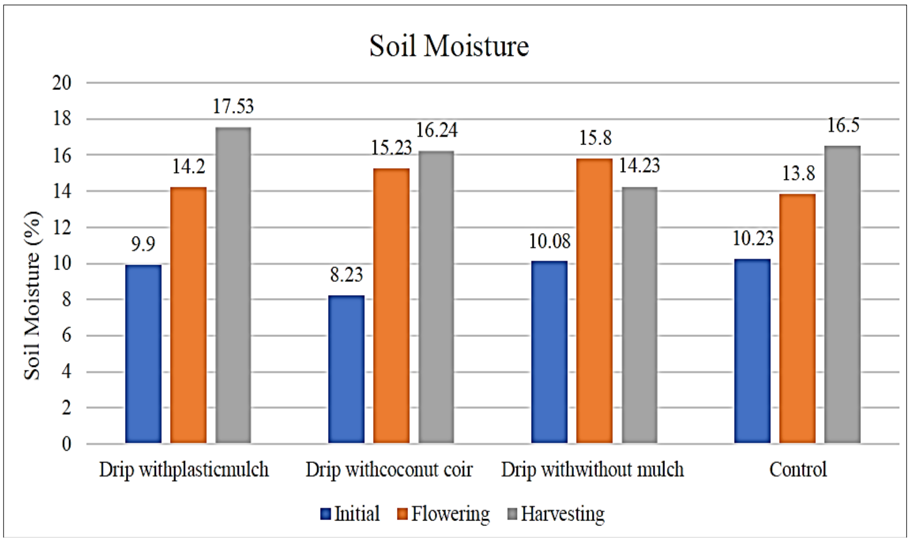

Fig 4.2: Comparison of Soil Moisture of soil before and after experimentation

4.5 Crop Yield: The drip irrigation in combination with different mulches significantly increased the yield of tomato as compared to drip irrigation without mulch (Table 4.7 & Fig 4.6). Among various treatments, the highest yield (2.018 t/ha) was recorded under drip with plastic mulch (A), followed by Drip irrigation with coconut coir (S) (1.412 t/ha), Drip with without mulch (M) (1.405 t/ha) and the lowest yield (0.873 t/ha) was recorded under conventional method of irrigation control (K). This might be due to water stress during the critical growth period, coupled with aeration problem in first few days immediately after irrigation. Another reason to get low yield by conventional practice of irrigation might be due to less availability of nutrients for crop growth due to leaching and high weed infestation between the crops. In drip irrigation system, water is applied at a low rate for a longer period at frequent intervals near the plant root zone through lower pressure delivery system, which increases the availability of nutrients near the root zone with a reduction in leaching losses. More nutrient availability, especially near the root zone might have increased the translocation of photosynthesis to storage organs resulting in an increased weight of tomato.

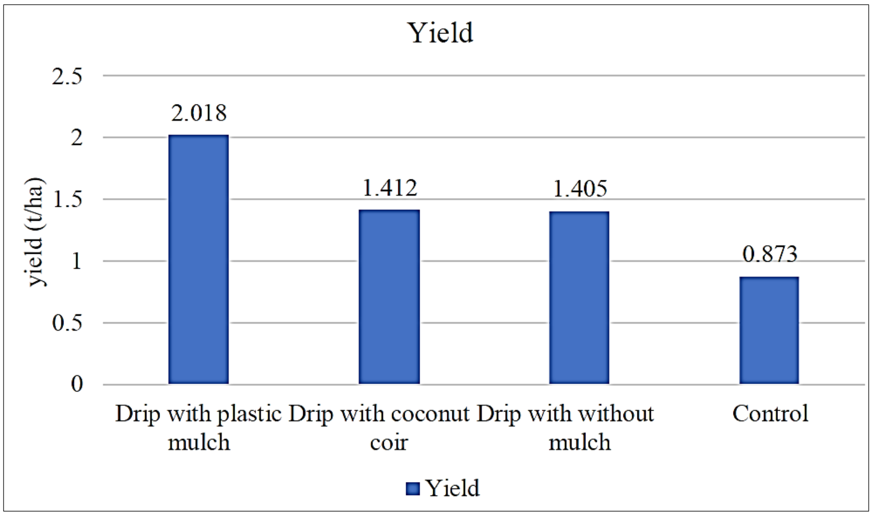

Fig 4.3: Yield data at different treatments

5. Conclusion

The main objective of the experiment is to study the effect of mulching system, drip irrigation system and control system on yield attributes, growth performance and water use efficiency (WUE) of tomato crop during summer season in red sandy soil. The crop duration of tomato crop was 90 days from January 1st week to April 1st week. The fertilizers and pesticides were applied to enhance the fertility status of soil and protect the crop from diseases and insects as per the recommendations.

This entire area of the experimental plot was divided based on the four treatments namely Drip with plastic mulch (A), Drip with coconut coir (S), Drip with without mulch (M) and control (K). Irrigation scheduling of tomato crop was prepared as per the CROPWAT 8.0 calculations. Time of operation of the drip and conventional method of irrigation without mulch (control) systems for the different plots was calculated and operated daily as per the irrigation schedule.

Based on the irrigation scheduling of tomato for summer season, the irrigation system was operated and the final yield of different plots for different irrigation systems is evaluated. The water requirement for the tomato crop, moisture content, soil temperature, bulk density, sieve analysis, uniformity coefficient of drip system, yield and its attributes and water use efficiency are mainly discussed. The obtained results of bulk density at initial stage and harvesting stage values are within the permissible limit of sandy soil (1.3-1.8 gm/cm3) this indicates that the drip irrigation, drip under black plastic mulch, drip under live mulch and control have no effect on bulk density. Measurement of the crop water requirement could be estimated in CROPWAT8.0. The irrigation scheduling and duration for the tomato crop is estimated based on crop water requirement calculated by CROPWAT 8.0. The obtained results of uniformity coefficient of drip irrigation, drip under black plastic mulch, and drip under live mulch satisfy there commended condition (80% to 90%) for the field of drip irrigation system. The moisture content was greatest in the drip with plastic mulch, followed by control, coconut coir and drip without mulch treatments at a 15 cm depth. The soil temperature was observed highest in the conventional method of irrigation without mulch (control) followed by drip without mulch, drip with plastic mulch and drip with coconut coir at 15 cm depth.

CRediT authorship contribution statement

Vedantam Sai Krishna: Writing - review & editing, Writing - original draft, Supervision, Methodology, Data curation, Concept, Software, Methodology, Investigation. Also, Drafting & Editing, Validation, Resources, Investigation, Formal analysis, Data curation.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors take complete responsibility of the information presented in the manuscript and has not used Artificial Intelligence (AI) tools or bots in drafting the review paper.

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Declaration of competing interest

The authors declare that they have no financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability
No data was used for the research described in the article.

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