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Influence of drip irrigation and mulching practices on fruit set, yield and water use efficiency of litchi cv. rose scented in the Tarai region of Uttarakhand

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ABSTRACT: An experiment was conducted to study the combined effect of drip irrigation and mulching on fruit set, yield and water use efficiency of litchi cv. Rose Scented at the Horticulture Research Centre, Patharchatta of G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, during the year 2021. Litchi trees under the study were subjected to mulching with different types of materials (black polythene and white polythene) and supplied with drip irrigation. The combined application of drip irrigation and black polythene mulch significantly improved fruit set, fruit retention, yield and WUE compared with flood irrigation and non-mulched treatments. Highest fruit set (30.07 %) was found in the treatment DI_2M_1 (75% ER with black polythene mulch). Maximum WUE (9.59 kg m^{-3}) was observed under the treatment DI_1M_1 (50% ER with black polythene mulch), indicating improved water productivity under deficit irrigation with mulching. Thus, drip irrigation along with black polythene mulch can be recommended to litchi growers to enhance fruit set, increase yield and productivity and improve water use efficiency of the orchard. The water use efficiency was higher (7.41 kg/m^3) with 100% ER with black polythene mulch and saved 25.92 % irrigation water in comparison to control.

Key words: Drip Irrigation, ER (Evaporation Replenishment), Litchi, Mulching, Rose Scented

Litchi (*Litchi chinensis* Sonn.), popularly known as the “Queen of Fruits,” is an important subtropical fruit crop belonging to the family Sapindaceae. It is widely cultivated for its attractive bright-red fruits, which are valued for their distinctive aroma, excellent flavour, and high consumer appeal. The fruits are primarily consumed fresh but are also processed into canned and dried products. Phylogenetically and historically, its primary center of origin is localized to the subtropical regions of Southern China, specifically within the Guangdong and Fujian provinces (Kumar, 2020). On a global scale, India is the second-largest producer of litchi, trailing only China in both total cultivation acreage and annual yield (Sahni *et al.*, 2020). Based on the 2018 National Horticulture Board (NHB) datasets, the national cultivation footprint extends across approximately 95,000 hectares, generating a gross annual output of 727,000 metric tonnes (Mt). The largest area and production of litchi are concentrated in Bihar, with West Bengal ranking second. Other commercially significant litchi growing states

comprise Jharkhand, Assam, Chhattisgarh, Uttarakhand, Punjab, Odisha, and others. Litchi fruit is recognized as a rich source of bioactive compounds and essential nutrients, including polysaccharides, vitamins, minerals, and a diverse range of polyphenolic constituents such as flavonoids, phenolic acids, terpenes, steroids, and flavan-3-ols, which contribute to its antioxidant, functional, and nutraceutical value (Savita, B *et al.*, 2020; Qu *et al.*, 2021). In addition to these beneficial phytochemicals, the fruit contains naturally occurring compounds such as nitrates, oxalates, and certain phenolic substances. These constituents occur at concentrations well within safe dietary limits and do not pose any significant risk to human health under normal consumption (Kumar *et al.*, 2020). “Rose Scented” cultivar of litchi is ready for harvest by the second week of June, demonstrating desirable horticultural traits yet remains highly prone to cracking, resulting in considerable yield losses. Conventional grower practices often involve excessive irrigation as a mitigation strategy against

cracking. However, escalating climate variability and the concomitant depletion of water resources necessitate a departure from such unsustainable practices. In the context of mounting water scarcity in Indian agriculture, there is an urgent imperative to refine and optimize the irrigation protocols for individual crops, particularly those as hydro-sensitive as litchi.

Mulching involves the application of organic or inorganic materials on the soil surface. This practice has emerged as a critical agronomic intervention for the sustainable production of high-value horticultural crops. Given the perennial nature of fruit trees, they are particularly susceptible to fluctuations in rhizosphere moisture, edaphic thermal regimes and inter-species competition (weeds); mulching serves as a regulatory buffer against these limiting factors (Parmar *et al.*, 2025). The practice of mulching in fruit crops helps reduce water loss through evaporation, stabilize soil temperature, and conserve soil moisture (Bhan *et al.*, 2025). The present study was therefore conducted to evaluate the effects of regulated irrigation at predetermined intervals, in conjunction with mulching, a well-established water conservation technique, on fruit set, yield and water use efficiency of litchi.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted during 2021 at the Horticulture Research Centre (HRC), Patharchatta, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand. The centre is located in the *tarai* region which lies at 29° North latitude, 79.3° East longitude and at an altitude of

243.84 meters above MSL. The experimental site is characterized by a humid subtropical climate, marked by pronounced seasonal thermal extremes, arid summers and cold winters. Summer temperatures typically range from 32 to 45°C, while winter temperatures fluctuate between 0 and 9°C. The region receives an average annual precipitation of approximately 1200 mm, with the southwest monsoon typically commencing during the second or third week of June and persisting with substantial rainfall until the second week of September. Monthly meteorological observations, including maximum and minimum temperature, relative humidity, rainfall, sunshine hours and pan evaporation, were obtained from the Agrometeorological Observatory, Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, during the experimental period (January–June 2021). The summarized monthly weather conditions prevailing during the study are presented in Table 1. The meteorological week's average weather data of 2021 (January to June).

Soil Characteristics

Before applying the treatments, composite soil samples were randomly collected from the experimental plot using a screw auger at a depth of 0-30 cm. These collected samples were thoroughly mixed, and from the mixture, a representative soil sample was extracted for physio-chemical analysis. The experimental site was characterized by a Mollisol with a silt-textured soil, possessing favourable water-holding capacity. The soil was slightly acidic (pH 6.42), containing 0.65% organic carbon, with available nitrogen, phosphorus, and potassium levels of 182.38, 29.19, and 218.93 kg ha⁻¹, respectively. These physicochemical properties

Table 1: Monthly meteorological conditions during the experimental period (January–June 2021)

	Temp. (Max.)	Temp (Min.)	RH (712)	RH (1412)	Rainfall (mm)	Sunshine hrs.	Wind Velocity (km/hr)	Evap. (mm)
Jan.	18.4	8.4	96	69	18.6	3.2	2.4	1.8
Feb.	25.2	8.9	92	48	4.6	6.2	2.4	2.8
March	30.5	13.2	85	35	0.0	7.8	3.6	4.7
April	34.5	15.4	58	15	4.1	8.8	4.6	8.0
May	37.0	21.3	73	46	190.6	7.5	4.3	5.9
June	37.0	24.9	80	57	132.0	7.2	5.0	5.2

provided suitable conditions for the growth and evaluation of the experimental crop.

Experimental Study

The investigation was conducted on twenty-one-year-old litchi trees (cv. Rose Scented), established under a high-density planting system with a spacing of 5 m × 5 m. A total of 78 phenotypically uniform, healthy and vigorously growing trees were selected for the study. Uniform cultural practices were meticulously maintained across the entire orchard throughout the experimental duration to ensure homogeneity and minimize extraneous variability. The experiment was laid out by using Randomized Block Design (RBD) with thirteen treatments replicated three times and in each replication two trees were taken as a unit. F test was used to calculate mean differences at 5 percent level of significance. Critical difference (CD) at 5 percent level of probability was used for comparing the data.

The observations on vegetative growth were recorded twice, once in February, 2021 and again data were recorded in June, 2021. Fruit set (%), fruit drop (%), fruit retention (%) and fruit cracking (%) were recorded on selected tagged branches. Eight branches in each tree were randomly selected and tagged for recording data. Number of fruits per panicle, number of fruits at harvest (per tree), fruit yield (kg/tree), yield per hectare (t/ha), water use efficiency (kg/m³) were calculated. For the

calculation of different parameters following formulas were used:

Fruit set percentage

For the calculation of percent fruit set, the average of total number of initially set fruits per panicle in all the tagged panicles was divided by the average number of female flowers per panicle. The fruit set percentage was calculated by using the following formula:

$$\text{Fruit set (\%)} = \frac{\text{Number of fruits per panicle}}{\text{Number of female flowers per panicle}} \times 100$$

Fruit drop percentage

The number of dropped fruits was calculated by subtracting average number of fruits harvested per panicle from the average number of fruit set initially. The fruit drop percentage was calculated by using following formula:

$$\text{Fruit drop (\%)} = \frac{\text{Number of fruits dropped}}{\text{Number of fruit set initially}} \times 100$$

Fruit retention percentage

The number of fruits retained was calculated by counting the average number of fruits harvested per panicle. The fruit retention percentage was calculated by using following formula:

$$\text{Fruit retention (\%)} = \frac{\text{Number of fruits retained}}{\text{Number of fruit set initially}} \times 100$$

Fruit cracking percentage

Fruit cracking was calculated by the following formula:

$$\text{Fruit cracking (\%)} = \frac{\text{Average number of cracked fruits at the time of harvesting}}{\text{Total number of fruits at the time of harvesting}} \times 100$$

Table 1: Treatment details

Treatment Code	Treatment description
DI ₁ M ₁	50% ER through drip irrigation + Mulching with 100 micron UV stabilized black polythene mulch
DI ₂ M ₁	75% ER through drip irrigation + Mulching with 100 micron UV stabilized black polythene mulch
DI ₃ M ₁	100% ER through drip irrigation + Mulching with 100 micron UV stabilized black polythene mulch
DI ₄ M ₁	125% ER through drip irrigation + Mulching with 100 micron UV stabilized black polythene mulch
DI ₁ M ₂	50% ER through drip irrigation + Mulching with 100 micron UV stabilized white polythene mulch
DI ₂ M ₂	75% ER through drip irrigation + Mulching with 100 micron UV stabilized white polythene mulch
DI ₃ M ₂	100% ER through drip irrigation + Mulching with 100 micron UV stabilized white polythene mulch
DI ₄ M ₂	125% ER through drip irrigation + Mulching with 100 micron UV stabilized white polythene mulch
DI ₁ M ₀	50% ER through drip irrigation + Without mulch
DI ₂ M ₀	75% ER through drip irrigation + Without mulch
DI ₃ M ₀	100% ER through drip irrigation + Without mulch
DI ₄ M ₀	125% ER through drip irrigation + Without mulch
Control	Flood irrigation

Yield per hectare

Yield per hectare was calculated by multiplying the yield obtained per tree and number of plants per hectare. In this case,

$$\text{Number of plants per hectare} = \frac{10000 \text{ m}^2}{5 \text{ m} \times 5 \text{ m}}$$

The average yield per hectare was worked out and is expressed as tonnes per hectare (t/ha).

Water use efficiency

Water use efficiency under drip irrigation is calculated as the ratio of yield obtained to the quantity of water applied per tree in each treatment throughout the duration of experiment. The formula used for calculation is:

$$\text{Water use efficiency (kg/m}^3\text{)} = \frac{\text{Yield (kg)}}{\text{Water consumed (m}^3\text{)}}$$

The irrigation water requirement (V) was determined on the basis of crop evapotranspiration (in litres/plant) as per the formula suggested by Vermeiren and Jobling (1984):

$$V = E_p \times K_p \times K_c \times K_r \times \text{Ground cover area}$$

Where, E_p : Pan evaporation (mm/day); K_p : Pan Coefficient (0.85); K_c : Crop coefficient (0.65); K_r : Reduction coefficient (0.1+ percent ground cover) The pan evaporation data were collected from agrometeorological observatory located near the experimental site (Table 1). The pan coefficient value was adopted as suggested in FAO-56. The uniform K_c value of 0.85 throughout the fruiting season was adopted for litchi trees (Bredell, 1971). The drip irrigation was applied through lateral lines with eight emitters per tree that discharged water @ 8 litres per hour per emitter. The irrigation in different treatments was maintained through control valves that were placed at the beginning of each lateral line. Drip irrigation system was operated daily from 25.03.2021 to 04.06.2021. In control trees, flood irrigation was also done on the daily basis and 100% ER was supplied as flood irrigation. The experimental trees were subjected to drip irrigation at four levels of evaporation replenishment (ER), viz. 50% ER, 75% ER, 100% ER and 125% ER with three mulching treatments e.g., 100-micron UV stabilized black polythene mulch (BPM, 100-micron UV stabilized white polythene mulch (WPM) and No mulch (NM). The trees under control were

irrigated through flood irrigation.

Statistical Analysis

The experimental data were systematically compiled, tabulated and analysed using MS Excel and OPSTAT (<https://opstat.somee.com/opstat/>) statistical website. Analysis of variance (ANOVA) was performed following the Randomized Block Design (RBD) methodology as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Fruit Set and Fruit Cracking

The integration of drip irrigation (DI) and mulching significantly influenced the reproductive parameters of litchi (Table 1). The maximum fruit set (30.07%) was recorded under the treatment DI_2M_1 (75% ER + black polythene mulch). In contrast, the minimum (22.77%) was observed in DI_1M_0 (50% ER + no mulch), which was statistically comparable with both the control (flood irrigation) and DI_1M_2 . The enhanced fruit set under the treatment can be attributed to the constant availability of water without much evaporative losses due to mulching during flowering and fruit set stage which ensures better uptake of nutrients and leads to increased photosynthesis and assimilate.

Regarding post-setting dynamics, the treatment DI_3M_1 (100% ER + black polythene mulch) exhibited the most favourable outcomes, including the highest fruit retention (17.88%), the lowest fruit drop (82.12%), and the minimum fruit cracking (8.72%). Conversely, the highest incidence of fruit cracking (15.87%) and fruit drop (87.62%) occurred under the moisture-stressed conditions of DI_1M_0 . The increase in fruit retention under the treatment may be due to the constant irrigation which help in protecting trees from stress conditions and thereby enhancing retention. Also, mulching helps in conserving moisture and preventing evaporative losses. These findings align with Ghosh *et al.* (2020), Saikia *et al.* (2022) and Mahato *et al.* (2020), who noted 100% fruit retention and drop reduction in sweet orange. The tendency of fruit skin cracking is a serious postharvest problem of litchi fruit Gogoi

et al. (2020).

The reduction in fruit cracking under drip irrigation and mulching can be attributed to the maintenance of consistent soil moisture and enhanced nutrient bioavailability in the rhizosphere. Fruit cracking, a critical physiological malady in litchi, is primarily triggered by fluctuations in soil moisture. Mulching mitigates this by buffering the root zone against moisture stress.

Yield and Water Use Efficiency (WUE)

Data presented in Table 2 indicate significant variations in yield-contributing traits and WUE. The treatment DI_3M_1 (100% ER + black polythene mulch) produced the superior fruit yield (34.64 kg tree⁻¹; 13.86 t ha⁻¹), characterized by the highest number of fruits per panicle (14.16) and fruits at harvest (1,386.33 per tree). This was closely followed by DI_2M_1 . The lowest productivity (7.64 t ha⁻¹) was recorded in DI_2M_0 . The augmentation in

Table 2: Effect of drip irrigation and mulching on fruit set, fruit drop, fruit retention and fruit cracking

Treatment	Quantity of water applied (Litres/tree*)	Fruit set (%)	Fruit drop (%)	Fruit retention (%)	Fruit cracking (%)
DI_1M_1	2336.72	24.14	85.14	14.86	12.26
DI_2M_1	3505.08	30.07	82.72	17.28	9.27
DI_3M_1	4673.44	28.83	82.12	17.88	8.72
DI_4M_1	5841.80	27.75	83.59	16.40	10.07
DI_1M_2	2336.72	23.83	86.17	13.83	14.58
DI_2M_2	3505.08	27.91	83.64	16.36	11.66
DI_3M_2	4673.44	27.33	83.12	16.88	10.45
DI_4M_2	5841.80	25.44	83.85	16.15	12.06
DI_1M_0	2336.72	22.77	87.62	12.37	15.87
DI_2M_0	3505.08	24.45	84.95	15.05	14.87
DI_3M_0	4673.44	26.29	84.45	15.55	12.91
DI_4M_0	5841.80	24.22	84.19	15.81	12.41
Control	6309.14	23.53	85.31	14.68	15.59
C.D. at 5%		1.06	1.87	1.87	3.52
SE(m)		0.36	0.64	0.64	1.20

* During the entire irrigation period.

Table 3: Effect of drip irrigation and mulching on number of fruits per panicle, number of fruits at harvest, fruit yield and water use efficiency

Treatment	No. of fruits per panicle	No. of fruits at harvest (per tree)	Fruit yield (kg/tree)	Yield per hectare (t/ha)	Water use efficiency (kg/m ³)
DI_1M_1	6.17	1033.17	22.41	8.96	9.59
DI_2M_1	12.17	1358.50	32.32	12.93	9.22
DI_3M_1	14.16	1386.33	34.64	13.86	7.41
DI_4M_1	11.83	1256.17	30.79	12.32	5.27
DI_1M_2	5.17	1048.67	21.33	8.53	9.13
DI_2M_2	10.00	1287.50	29.87	11.95	8.52
DI_3M_2	11.83	1307.00	31.92	12.77	6.83
DI_4M_2	9.50	1237.33	29.58	11.83	5.06
DI_1M_0	5.00	950.67	19.11	7.64	8.18
DI_2M_0	7.50	1068.50	24.24	9.70	6.92
DI_3M_0	8.67	1145.83	27.32	10.93	5.85
DI_4M_0	7.83	1211.33	29.12	11.65	4.98
Control	5.50	919.50	20.47	8.19	4.38
C.D. at 5%	4.50	53.43	1.50	0.60	0.47
SE(m)	1.53	18.20	0.51	0.20	0.16

yield is likely due to optimized soil-water-plant relationships, which enhance nutrient solubility and the translocation of assimilates. This finding corroborates the results reported by Tyagi. (2021) in litchi. Yield of the tree depends on many factors that include nutritional factors (Gogoi *et al.*, 2020), management practices, climate and locality of the tree which explains the increase in yield under the treatment. These observations are consistent with studies on ber (Brar *et al.*, 2020), wherein drip irrigation coupled with mulching consistently resulted in a higher number of fruits and improved yield.

Maximum WUE (9.59 kg/m³) was attained under DI₁M₁, indicating that lower irrigation levels combined with mulching optimize water productivity. In contrast, flood irrigation (Control) resulted in the lowest WUE (4.38 kg/m³) due to excessive evaporative and percolation losses. The higher WUE under deficit irrigation levels indicates more efficient utilization of applied water Ghosh *et al.* (2020) also has reported similar findings.

CONCLUSION

Overall, the study demonstrates that the integration of drip irrigation with plastic mulching is an effective water management strategy for litchi cultivation, as it not only improves fruit set, retention and yield but also reduces physiological disorders such as fruit cracking. The study concludes that the synergistic application of drip irrigation and black polythene mulch significantly enhances litchi productivity. For maximum fruit set and yield, 100% ER with black polythene mulch is recommended. However, in water-scarce regions, 50-75% ER with black polythene mulch serves as an efficient strategy to maximize water use efficiency without substantial yield loss. Adoption of this practice can contribute to sustainable orchard management and improved productivity in litchi cultivation.

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