



# Effect of Water Sprinkling over Tree Canopy on Fruit Cracking, Quality and Yield of Litchi Fruits

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## **Authors' contributions**

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## **ABSTRACT**

Litchi (*Litchi chinensis* Sonn.) is an important subtropical evergreen fruit crop of Sapindaceae family. Fruit cracking is a serious problem in litchi happen during fruit growth and its development. Fruit cracking affect significant loss of economic yield. Fruit cracking in litchi coincides with a period characterized by high day temperature (35-40°C) and low relative humidity (60%). Effect of water sprinkling over tree canopy on fruit cracking, quality and yield of litchi crop was evaluated under four treatments, namely T<sub>1</sub> (4 micro-sprinklers per tree), T<sub>2</sub> (3 micro-sprinklers per tree), T<sub>3</sub> (2 micro-sprinklers per tree), and T<sub>4</sub> (without micro sprinkler) as control. Micro-sprinklers were tested for their hydraulic performance. Result revealed that, minimum fruit cracking, i.e. .20.03, 18.49, 13.76 and 4.55% was observed at 1.0, 1.5, 2.0 and 3.0 hours of water sprinkling under treatment T<sub>1</sub>. Highest yield (i.e. 65.27 q/ha) and better quality of fruits were also found in treatment T<sub>1</sub>. Contrary to this, maximum fruit cracking (30.16%), lowest yield (33.52 q/ha) and satisfactory quality of fruits were found in treatment T<sub>4</sub> (control). Linear relationship between discharge and pressure; and exponential relationship between pressure and wetted diameter were found for performance of micro sprinklers.

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## 1. INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an important subtropical evergreen fruit crop of Sapindaceae family. Fruit cracking is a serious physiological disorder in litchi that occurs during its growth and development, and causes significant loss of economic yield. Fruit cracking in litchi coincides with a period characterized by high day temperature (35-40°C) and low relative humidity (60%). It entails the implicated roles of both internal and external factors [1]. In India, although commercially predominant in the Indo-Gangetic plains of Uttar Pradesh, Bihar, Uttarakhand and West Bengal, suitable climatic conditions in the sub-tropical states of Punjab, Himachal Pradesh and Jammu and Kashmir has further expands its cultivation. The annual production of litchi in India is 528 260 metric tonnes from an area of 84 950 ha [2] mainly restrained to Bihar (38%). Despite of unique and desirable characteristics, litchi fruit is seriously affected by fruit cracking disorder that causes significant loss of yield and commercial value [3].

North Bihar falls under humid climate. A large area of this region is affected by flood problems during monsoon season and drought in summer, causing diversity in farming system. Mango and litchi are the main horticultural crops in the north Bihar. In Bihar about 28.4 thousand hectares of land is under litchi cultivation. Average state yield of litchi crop is about 10.0 t/ha [4]. Furthermore, litchi fruits are not of export quality, as result, litchi growers are not getting good price for their produce.

Apart from the factors, like soil, water and fertilizer, affecting the crop yield, the cracking of fruits is also one of the main factors of poor yield performances. Fruit cracking causes not only to deteriorate the fruit quality, but also reduces the yield to a significant level. Cracking of litchi fruit is mainly affected by weather parameters, such as temperature and humidity. At high humidity, skin of litchi fruit becomes moistened, as result the skin expands easily according to increase in volume of aril inside the fruit; which leads to check the fruit cracking. On contrast, at high temperature, fruits are cracked due to lack of moisture in the skin. Looking these facts, an attempt has been made in present study, to evaluate the effect of water sprinkling over canopy of litchi trees on cracking, yield and quality of the litchi fruits. Application of irrigation

at 40% pan coefficient through sprinkler irrigation had significant effect to overcome the cracking problem of fruit. Drip irrigation and mulching with fallen lychee leaves was also found effective to tackle the disorder. Use of agro-shade net (50% light transmission) and foliar application of Boron at 0.5% had potential influence to control this disorder. Besides, delayed harvesting by the application of gibberellic acid (50 mg L<sup>-1</sup>) at 21 days after fruit set also reduced the problem [5]. Fruit cracking in litchi coincides with a period characterized by high day temperature (35-40°C) and low relative humidity 60%) [3]. Irrigation gave best result in checking fruit cracking when bearing trees are irrigated at 100% evapotranspiration replenishment [6]. Irrigation at 20% pan coefficient in conjunction with sprinkler irrigation or placement of dessert cooler was highly efficient in control fruit cracking [7]. Fertigation comprising of 100% of the estimated irrigation and 137.50% of the recommended fertilizers dose minimized fruit cracking [8]. Rani et al. [9] observed a significant reduction in cracking rate with application of vermicompost @ 75 kg/tree.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Details

Experiment was conducted at Horticultural Research Station, Birauli, located at the distance of about 5 Km from the university headquarter, on Pusa-Samastipur road under "Precision Farming Development Centre (PFDC)" financed by the National Committee on Plasticulture Application in Horticulture (NCPAH), Ministry of Agriculture and Farmers Welfare, GoI, New Delhi, running in the Department of Soil & Water Engineering, College of Agricultural Engineering, Pusa, Samastipur. The altitude, latitude and longitude of the site is 52.92 m MSL, 25°29'N and 83°48'E, respectively. Climate is sub-humid and sub-tropical with average annual rainfall varies up to 1200 mm, out of 75% is received during monsoon months (July to September) and rest during other seasons of year. The temperature varies minimum 6°C in January to maximum 45°C in month of June. The maximum humidity varies from 80 to 90 % during rainy month, while minimum from 40 to 60% during summer months. Highest solar radiation is received 650ly/day (average) in the month May, while lowest 380 ly/day (average) in the month December. Soil is sandy clay loam with average moisture content 12.01 per cent.

Drip irrigation system consists of water source, pumping unit, pipelines and micro-sprinklers. Cavity tube well was used as the water source, which was operated by a 7.5 H.P diesel engine. The pipeline consists of main, sub-main and laterals, in which main pipeline were used to convey the water from pumping unit to litchi field. The sub-main pipe line was installed in the litchi field to deliver water into laterals. Micro-sprinklers were connected to the laterals and tied over tree canopy.

## 2.2 Package and Practices

Experiment was performed on a litchi (Sahi-early variety) orchard of 12 years old plantation in the area of about 1 acre. Plant-to-plant and row-to-row spacing of tree was 8m x 8m. Four treatments, i.e. T<sub>1</sub> (4 micro-sprinklers per tree); T<sub>2</sub> (3 micro-sprinklers per tree); T<sub>3</sub> (2 micro-sprinklers per tree) and T<sub>4</sub> (without micro-sprinklers) as control with five replications were applied. Water was sprinkled 12 times from mid-March to the end of May for 1, 1.5, 2 and 3 hours per day in each treatment as per requirement of plants. N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O were applied @ 750, 200 and 400 g / tree, respectively, in two split doses. First dose was applied @ 50% N, 50% K<sub>2</sub>O and 100% P<sub>2</sub>O<sub>5</sub> after harvesting the fruit in previous season, i. e. in the last week of June. Second dose was applied @ 50% N and 50% K<sub>2</sub>O in the month of April. Pesticides and insecticides were not applied. Weeds were removed manually, four times in the year.

## 2.3 Sprinkler's Testing

Micro-sprinkler was tested for evaluating its hydraulic behaviour. Sprinkling system was operated for collecting the data on discharge, wetted diameter and water pressure. Discharge was measured by collecting the water droplets in container; wetted diameter, i.e. width of wetted soil surface was measured with the help of measuring tape at different points; and pressure was measured with the help of pressure gauge installed in the system. Relationships between pressure & discharge and pressure & wetted diameter were developed.

## 2.4 Observations and Evaluation

Sprinkling of water over tree canopy affects the tree environment (i.e. humidity and temperature), which effect the fruit cracking, biometrics, yield and quality of litchi fruits. Canopy humidity was measured at 1 hour interval from 9 A.M. to 2

P.M, daily during operation (Table-1) with the help of digital recorder.

Fruit cracking was evaluated by counting the number of cracked fruits out of total harvested fruits under different treatments. Variations in cracking percentage were determined with reference to the total number of cracked fruits under control treatment. Fruit biometrics, i.e. length and breadth of fruit were measured at different points of fruit periphery by using slide caliper. The mean value was considered as the average fruit size.

Yield was determined by considering the gross weight of fruit, i.e. sum of weights of seed, aril and skin, excluding cracked fruits. Organoleptic qualities of fruit were evaluated based on 10-point scale. Points were assigned on the basis of colour, taste and texture (softness/ hardness) of the fruit.

## 3. RESULTS AND DISCUSSION

### 3.1 Hydraulic Behavior of Micro-Sprinkler

Hydraulic behavior of micro-sprinkler was evaluated in terms of relationship between pressure and discharge; and pressure and wetted diameter. Linear relationship between discharge and pressure (Fig. 1); and exponential relationship between wetted diameter and pressure (Fig. 2) were found most suitable, given as under:

$$Q = 0.926P + 0.2805 \quad (3.1)$$

$$(R^2 = 0.9926)$$

and

$$D = 29.508 \exp 6382P \quad (1 < P < 3.5) \quad (3.2)$$

$$(R^2 = 0.9894)$$

where, Q is the discharge of the micro-sprinkler (lpm); P is the pressure (Kg / cm<sup>2</sup>) and D is the wetted diameter (cm).

### 3.2 Effect of Water Sprinkling

#### 3.2.1 Canopy humidity

As shown in Fig 3, it was found that the level of canopy humidity increases with increase in number of micro-sprinklers and sprinkling hours. In treatment T<sub>1</sub>, in which 4 micro-sprinklers were equipped at each tree, highest canopy humidity, i.e. 81.71, 85.83, 88.00 and 91.90% at 1.5, 2.0,

2.5 and 3-hours of water sprinkling was noticed. Similarly, in treatment T<sub>2</sub> (3 micro-sprinklers), the canopy humidity was noticed to the tune of 79.18, 80.18, 84.53 and 87.41 % ; and in treatment T<sub>3</sub> (2 micro-sprinklers), it was 78.22, 78.62, 81.00 and 85.34 % ,respectively at 1.5 , 2.0, 2.5 and 3-hours of water sprinkling. In control treatment T<sub>4</sub> (without micro-sprinklers), the canopy humidity was 77.47% only, which is lowest as compared to other treatments.

As compared to control treatment, the increase in canopy humidity was estimated to be 5.47, 2.21 and 0.79% at 1.0 hour; 10.79, 3.50 and 1.48% at 1.5-hours; 13.60, 9.11 and 4.56% at 2.0- hours and 18.62, 12.83 and 10.16% at 3-hours of water sprinkling, respectively under treatments T<sub>1</sub> , T<sub>2</sub> and T<sub>3</sub> ( Table-1).

The canopy humidity was also found in increasing trend with increase in duration of water sprinkling (Table-1) in all treatments, except T<sub>4</sub> (control), e.g. in treatment T<sub>1</sub> the canopy humidity was recorded as 81.71, 85.83, 88.00 and 91.90%, respectively at 1.0, 1.5 2.0 and 3-hours of water sprinkling. It is mainly due to variations in amount of water application over canopy. At high water application rate, canopy gets more water, due to which humidity was raised to a higher limit.

### 3.2.2 Fruit cracking

The effect of water sprinkling on fruit cracking under different treatments and at different durations of sprinkling are shown in Table 2. On comparison, it was found that amongst four treatments, the highest reduction in fruit cracking (33.58%) was in treatment T<sub>1</sub>, followed by 24.03% in treatment T<sub>2</sub> and 17.64% in treatment T<sub>3</sub> over control treatment (T<sub>4</sub>) at 1- hour of water sprinkling. Similarly, 38.69, 30.50 and 23.38% on 1.5 hours of water sprinkling; 54.38, 44.79 and 41.41% on 2 hours of water sprinkling; and 84.91, 60.64 and 52.45% reduction in fruit cracking was found on 3 hours of water sprinkling, respectively under treatments T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> as compared to control treatment (T<sub>4</sub>).

The field experiment revealed that, cracking percentage of litchi fruits was on decreasing trend with advancement of sprinkling duration. As shown in Fig. 3, the highest reduction in fruit cracking was under treatment T<sub>1</sub> followed by T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> at all durations of water sprinkling.

Cracking of litchi fruits is significantly affected by the canopy humidity. At high humidity the fruit

skin gets more wetness, which results into easy expansion of skin according to increase in volume of aril in litchi fruit. On contrast, at less humidity the fruit skin remains hard, as result skin is likely to get cracked due to increase in volume of aril. In treatment T<sub>1</sub>, greater amount of water was sprinkled over tree canopy than the other treatments, causing development of high humidity inside the canopy and thereby reducing fruit cracking. This result was also revealed by [3, 6 and 7].

### 3.2.3 Fruit biometrics

Variations in the fruit biometrics, i.e. fruit length and breadth under different treatments are shown in the Table-3. On comparison, it was found that the average fruit length was found maximum (32.7mm) in treatment T<sub>1</sub>, while minimum (30.3mm) in treatment T<sub>4</sub> (control). In treatments T<sub>2</sub> and T<sub>3</sub>, the average fruit lengths were found to be 32.0 and 31.65mm, respectively. Increase in fruit length was estimated to be 7.92% in treatment T<sub>1</sub>; 5.61% in treatment T<sub>2</sub>; and 4.45% in treatment T<sub>3</sub> over control treatment.

Average fruit width was also found to be maximum (29.1mm) in treatment T<sub>1</sub>, followed by 28.0 mm in treatment T<sub>2</sub>, 27.5 mm in treatment T<sub>3</sub> and minimum 24.5 mm in treatment T<sub>4</sub>. Increase in fruit breadth was 18.77% in treatment T<sub>1</sub> and minimum 12.24% in treatment T<sub>3</sub> as compared to control treatment.

Canopy humidity affects very much to the litchi fruits. In treatment T<sub>1</sub>, canopy humidity was highest, because of greater application of water over tree, which resulted into better fruit biometrics.

### 3.2.4 Organoleptic quality

Organoleptic qualities of litchi fruits, i.e. flavour, taste, colour and texture of fruits under different treatments are shown in Table-4, which revealed that the litchi fruits of excellent quality were found to be in treatment T<sub>1</sub>, i.e. when sprinkling of water was done with 4-micro-sprinklers, followed by fine quality in treatment T<sub>2</sub>, (when water was sprinkled with 3 micro- sprinklers), good quality in treatment T<sub>3</sub> (when water was sprinkled with 1 micro-sprinkler), and satisfactory quality of litchi fruits in treatment T<sub>4</sub> (control). Variation in fruit quality was mainly due to effect of canopy humidity.

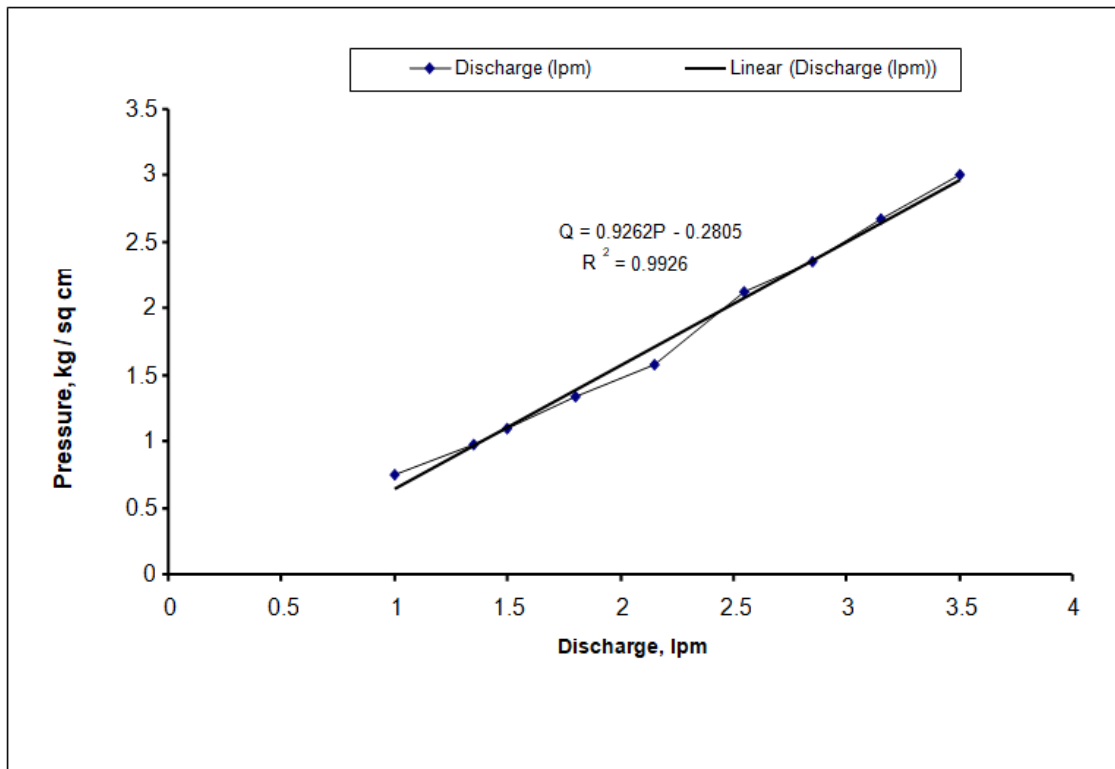


Fig. 1. Relationship between discharge and pressure

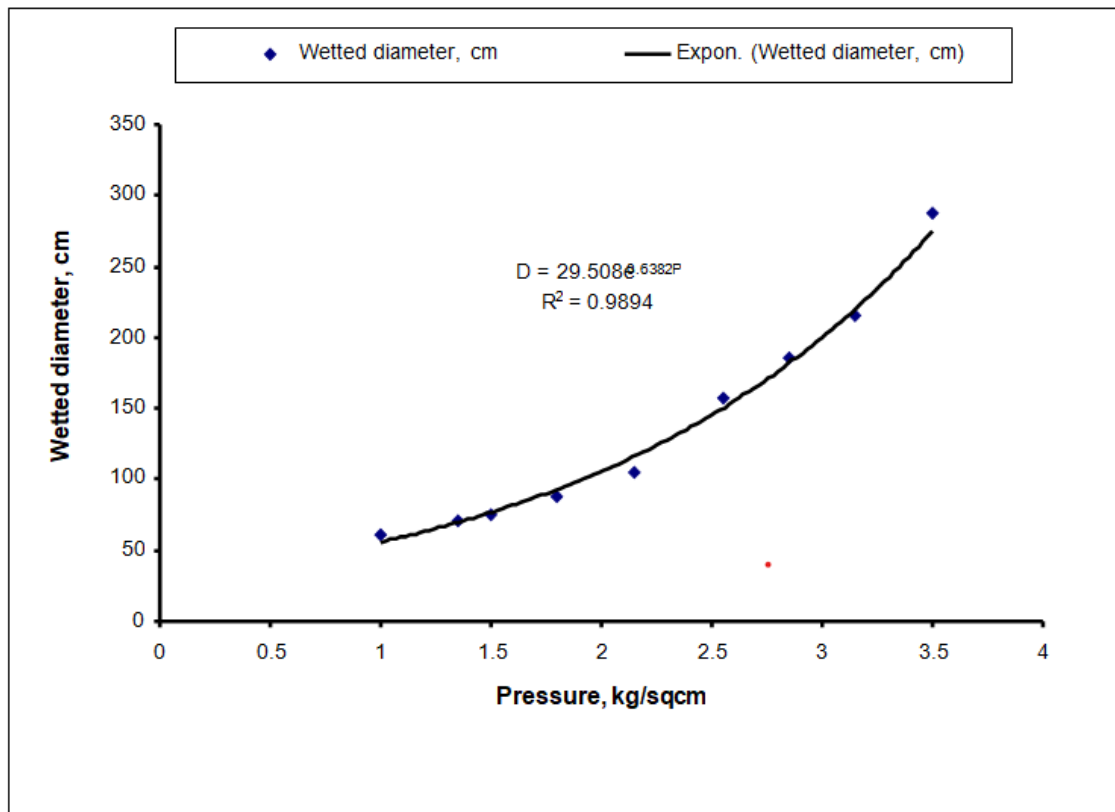


Fig. 2. Relationship between wetted diameter and pressure

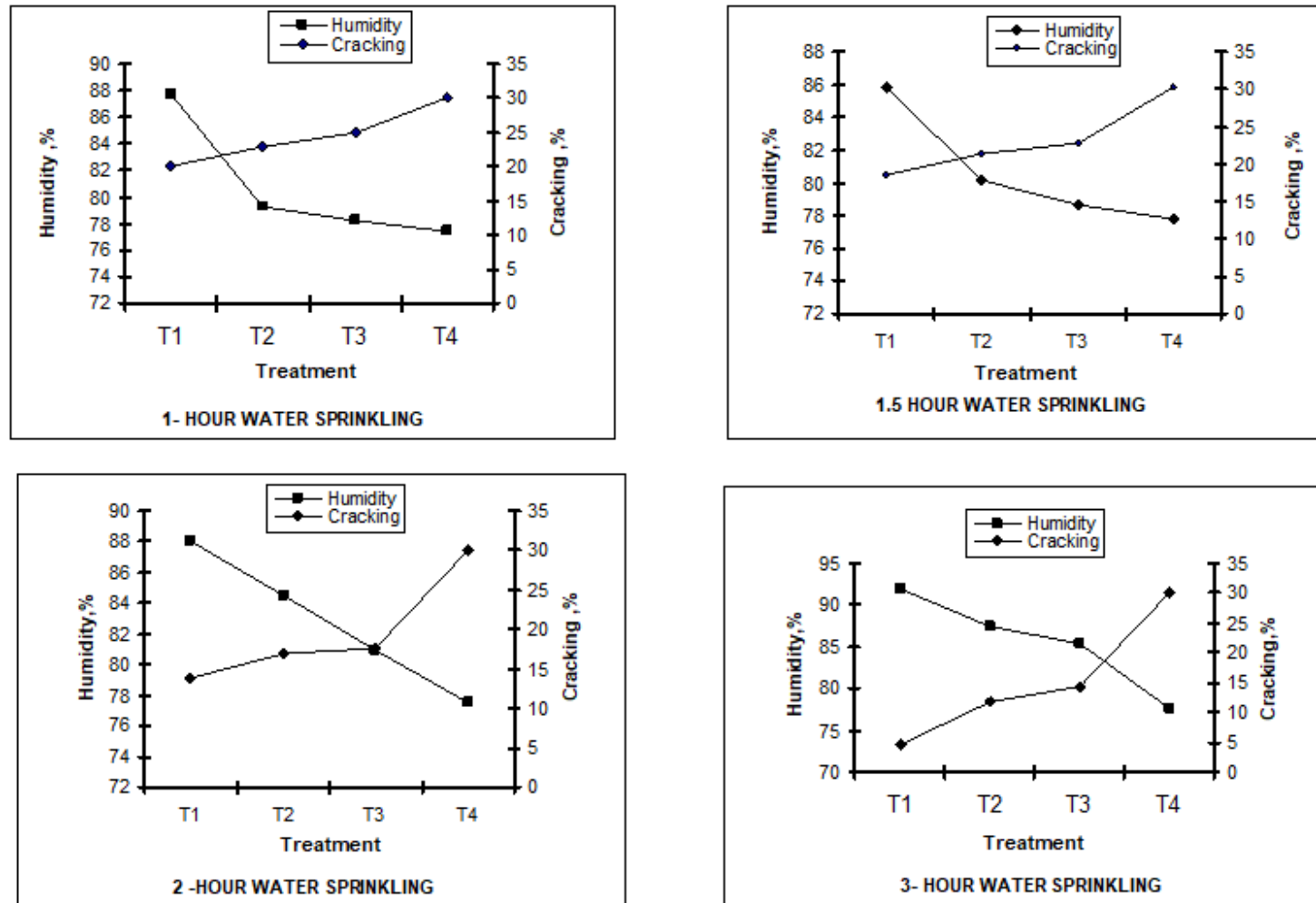


Fig. 3. Effect of humidity on fruit cracking at different hours of water sprinkling over tree canopy

**Table 1. Comparative variation in canopy humidity at different sprinkling hours [10-12]**

Treatment	Average humidity (%)			
	Sprinkling hour			
	1.0	1.5	2.0	3.0
T <sub>1</sub>	81.71(5.47 *)	85.83(10.79)	88.00(13.60)	91.90(18.62)
T <sub>2</sub>	79.18(2.21)	80.18(3.50)	84.53(9.11)	87.41(12.83)
T <sub>3</sub>	78.22(0.97)	78.62(1.48)	81.00(4.56)	85.34(10.16)
T <sub>4</sub>	77.47(-)	77.47(-)	77.47(-)	77.43(-)
C.D. at 5%	6.84041	5.45011	6.5685	9.2471
C.V.	10.603984	8.87087	10.7435	9.83025

\* Percent variation over control treatment

**Table 2. Comparative cracking percentage of fruits at different sprinkling hours**

Treatment	Sprinkling hour							
	1.0		1.50		2.00		3.00	
	Cracking percent *	Percent reduction over control	Cracking percent	Percent reduction over control	Cracking percent	Percent reduction over control	Cracking percent	Percent reduction over control
T <sub>1</sub>	20.03	33.58	18.49	38.69	13.76	54.38	4.55	84.91
T <sub>2</sub>	22.91	24.03	20.96	30.50	16.65	44.79	11.87	60.64
T <sub>3</sub>	24.84	17.64	23.11	23.38	17.67	41.41	14.34	52.45
T <sub>4</sub>	30.16	-	30.16	-	30.16	-	30.16	-
C.D. at 5%	6.4251	-	7.2612	-	6.58941	-	9.4587	-
C.V.	10.325	-	10.5371	-	8.7952	-	8.1653	-

\*Anonymous [10-12]

**Table 3. Fruit biometrics under different treatments [10-12]**

Treatment	Average length (mm)	Increment over Control (%)	Average breadth (mm)	Increment over control (%)
T <sub>1</sub>	32.7	7.92	29.1	18.77
T <sub>2</sub>	32.0	5.61	28.0	14.28
T <sub>3</sub>	31.65	4.45	27.5	12.24
T <sub>4</sub>	30.3	-	24.5	-
C.D. at 5%	5.3125	-	6.2157	-
C.V.	9.7842	-	10.1562	-

**Table 4. Organoleptic qualities of litchi fruits [10-12]**

Treatment	Colour (Avg. point)	Taste (Avg. point)	Texture (Avg. point)	Overall mean	Remark
T <sub>1</sub>	9.4	9.5	9.1	9.3	Excellent
T <sub>2</sub>	9.2	9.0	9.1	9.1	Fine
T <sub>3</sub>	8.8	8.5	8.9	8.73	Good
T <sub>4</sub>	8.1	7.5	7.4	7.66	Satisfactory

**Table 5. Average fruit yield under different treatments [10-12]**

Treatment	Average fruit weight (gm)	Average seed weight (gm)	Average of skin weight (gm)	Average aril weight (gm)	Yield (q/ha)	Increase in yield over control (%)
T <sub>1</sub>	21.24	4.27	4.70	11.0	65.27	94.72
T <sub>2</sub>	22.82	4.86	4.68	13.28	52.70	57.22
T <sub>3</sub>	19.60	4.22	3.78	11.60	45.62	36.10
T <sub>4</sub>	18.46	4.72	3.56	10.18	33.52	-
C.D. at 5%	5.7521	-	-	-	13.257	-
C.V.	9.1568	-	-	-	23.2567	-

### 3.2.5 Yield

Effect of water sprinkling over tree canopy on yield of litchi fruits is shown in Table 5, which noticed that on sprinkling of more water over tree canopy, as in treatment T<sub>1</sub>, the average fruit yield was highest to the tune of 65.27 q/ha, which is due to effect of canopy humidity. In other treatments, i.e. T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> the yield was found to be 52.70, 45.62 and 33.52 q/ha, respectively. In treatment T<sub>4</sub> (control) the reason of poor yield was low humidity because of not sprinkling the water over tree canopy. Percentage increase in fruit yield over control treatment was estimated to be 94.72 % in treatment T<sub>1</sub>; 57.22% in treatment T<sub>2</sub>; and 36.10 % in treatment T<sub>3</sub>.

## 4. CONCLUSIONS

The advantages offered by micro- sprinkler irrigation were explored in respect of reduction in fruit cracking; enhancement in yield and quality of litchi fruits by sprinkling the water over tree canopy. Experiment was conducted under 4

treatments with 5 replications for different sprinkling hours, to evaluate their effects on fruit characteristics and yield of litchi fruits.

Overall, a better effect on fruit cracking, biometrical properties and yield of litchi fruits was noticed under treatment T<sub>1</sub>, i.e. when 4 micro-sprinklers were used for water sprinkling. Important findings are summarized below:

1. Highest canopy humidity was noticed under treatment T<sub>1</sub>, i.e. when water was sprinkled with 4 micro sprinklers for 3-hours. Minimum fruit cracking was also found in treatment T<sub>1</sub> to the tune of 4.55% and maximum 30.16 % in treatment T<sub>4</sub> (control).
2. Average fruit length, breadth and yield were also found to be highest in treatment T<sub>1</sub>, i.e. 32.7mm, 29.1mm and 65.27 q/ha respectively, while minimum i.e. 30.3mm, 24.5mm and 33.52 q/ha, respectively in treatment T<sub>4</sub>. Organoleptic qualities of litchi fruits were found to be excellent in



treatment T<sub>1</sub> and satisfactory in treatment T<sub>4</sub>.

3. Hydraulic performance of micro-sprinklers revealed that the discharge and wetted diameter increase with increase in pressure. Linear relationship between pressure and discharge; and non-linear relationship (i.e. exponential) between pressure and wetted diameter were found to be most suitable.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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