Original Research Article

EFFECT OF WATER SPRINKLING OVER TREE CANOPY ON FRUIT CRACKING, QUALITY AND YIELD OF LITCHI FRUITS

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_1 (4 micro-sprinklers per tree), T_2 (3 micro-sprinklers per tree), T_3 (2 micro-sprinklers per tree), and T_4 (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_1. Highest yield (i.e. 65.27 q/ha) and better quality of fruits were also found in treatment T_1. Contrary to this, maximum fruit cracking (30.16%), lowest yield (33.52 q/ha) and satisfactory quality of fruits were found in treatment T_4 (control). Linear relationship between discharge and pressure; and exponential relationship between pressure and wetted diameter were found for performance of micro sprinklers.

Key Words: Micro-sprinkler irrigation, fruit cracking, yield and organoleptic quality of litchi fruit.

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 (Marboh et.al. 2017). 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 (Anon. 2015) 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 (Huang *et al*. 2005).

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 (Anon. 2006). 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^{-1}) at 21 days after fruit set also reduced the problem (Mandal et.al 2018). Fruit cracking in litchi coincides with a period characterized by high day temperature (35-40°C) and low relative humidity 60%) (Huang 2005). Irrigation gave best result in checking fruit cracking when bearing trees are irrigated at 100% evapotranspiration replenishment (Joshi *et al.* 2012). Irrigation at 20% pan coefficient in conjunction with sprinkler irrigation or placement of dessert cooler was highly efficient in control fruit cracking (Mitra *et al.* 2014). Fertigation comprising of 100% of the estimated irrigation and 137.50% of the recommended fertilizers dose minimized fruit cracking (Yadav *et al.* 2011). Rani *et al.* (2013) 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, $25^{o}29$'N and $83^{0}48$'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^{o}C in January to maximum 45^{o}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_1 (4 micro-sprinklers per tree); T_2 (3 micro-sprinklers per tree); T_3 (2 micro-sprinklers per tree) and T_4 (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_2O_5 and K_2O were applied @ 750, 200 and 400 g / tree, respectively, in two split doses. First dose was applied @ 50% N, 50% K_2O and 100% P_2O_5 after harvesting the fruit in previous season, i. e. in the last week of June. Second dose was applied @ 50% N and 50% K_2O 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 (Figure-1); and exponential relationship between wetted diameter and pressure (Figure-2) were found most suitable, given as under:

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

$$(R^2 = 0.9926)$$

and

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

$$(R^2 = 0.9894)$$

where, Q is the discharge of the micro-sprinkler (lpm); P is the pressure (Kg / cm ^{2}) 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_1, 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_2 (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_3 (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_4 (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_1 , T_2 and T_3 (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_4 (control), e.g. in treatment T_1 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_1, followed by 24.03% in treatment T_2 and 17.64% in treatment T_3 over control treatment (T_4) 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_1, T_2 and T_3 as compared to control treatment (T_4).

The field experiment revealed that, cracking percentage of litchi fruits was on decreasing trend with advancement of sprinkling duration. As shown in Figure-3, the highest reduction in fruit cracking was under treatment T_1 followed by T_2, T_3 and T_4 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_1, 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 (Huang. 2005, Joshi *et al.* 2012 and Mitra *et al.* 2014).

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_1, while minimum (30.3mm) in treatment T_4 (control). In treatments T_2 and T_3, 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_1; 5.61% in treatment T_2; and 4.45% in treatment T_3 over control treatment.

Average fruit width was also found to be maximum (29.1mm) in treatment T_1, followed by 28.0 mm in treatment T_2, 27.5 mm in treatment T_3 and minimum 24.5 mm in treatment T_4. Increase in fruit breadth was 18.77% in treatment T_1 and minimum 12.24% in treatment T_3 as compared to control treatment.

Canopy humidity affects very much to the litchi fruits. In treatment T_1, 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. flaour, 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_1, i.e. when sprinkling of water was done with 4-micro-sprinklers, followed by fine quality in treatment T_2, (when water was sprinkled with 3 micro-sprinklers), good quality in treatment T_3 (when water was sprinkled with 1 micro-sprinkler), and satisfactory quality of litchi fruits in treatment T_4 (control). Variation is fruit quality was mainly due to effect of canopy humidity.

3.2.4 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_1 ,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_2, T_3 and T_4 the yield was found to be 52.70, 45.62 and 33.52 q/ha, respectively. In treatment T_4 (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_1; 57.22% in treatment T_2; and 36.10 % in treatment T_3.

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_1, i.e. when 4 micro-sprinklers were used for water sprinkling. Important findings are summarized below:

1. Highest canopy humidity was noticed under treatment $T_{1,}$ i.e. when water was sprinkled with 4 micro sprinklers for 3-hours. Minimum fruit cracking was also found in treatment T_1 to the tune of 4.55% and maximum 30.16 % in treatment T_4 (control).
2. Average fruit length, breadth and yield were also found to be highest in treatment T_1, 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_4. Organoleptic qualities of litchi fruits were found to be excellent in treatment T_1 and satisfactory in treatment T_4.
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.

5. ACKNOWLEDGEMENTS

The authors gratefully acknowledge to the National Committee on Plasticulture Applications in Horticulture (NCPAH), Ministry of Agriculture & Farmers Welfare, Govt. of India which provide the fund for conducting the experiment under Precision Farming Development Centre (PFDC).

REFERENCES

Anonymous (2000). Annual report of Plasticulture development Scheme, submitted to National Committee on Use of Plastics in Agriculture, M.O.A, New Delhi, Department of Soil & Water Conservation Engineering, College of Agricultural Engineering, R.A.U. Pusa (Samastipur), Bihar.

Anonymous (2001). Annual report of Plasticulture development Scheme, submitted to National Committee on Use of Plastics in Agriculture, M.O.A, New Delhi, Department of Soil & Water Conservation Engineering, College of Agricultural Engineering, R.A.U. Pusa (Samastipur), Bihar.

Anonymous (2002). Annual report of Plasticulture development Scheme, submitted to National Committee on Use of Plastics in Agriculture, M.O.A, New Delhi, Department of Soil & Water Conservation Engineering, College of Agricultural Engineering, R.A.U. Pusa (Samastipur), Bihar.

Anonymous. 2006. National Horticulture Board Database. National Horticulture Board, Gurgaon, Haryana

Anonymous. 2015. National Horticulture Board Database. National Horticulture Board, Gurgaon, Haryana.

Huang, X M. (2005). Fruit disorders.(*In*:) *Litchi and Longan - Botany, Production and Uses*, pp 41–152. Menzel C and Waite G K (Eds). CABI Pub., Wallingford, Oxford, UK.

Joshi G, Singh, P K, Srivastava P C and Singh S K. (2012). Effect of mulching, drip irrigation scheduling and fertilizer levels on plant growth, fruit yield and quality of litchi (*Litchi chinensis* Sonn.). *Indian Journal of Soil Conservation* 40(1): 46–51

Mandal, D. and Mitra, S. (2018). Cracking of lychee fruits: responsible factors and control. Acta Hortic. 1211, 35-44.

Marboh, E. S., Singh, S. K., Pandey, S., Nath, V. Gupta, A. K and Pongener, A. (2017). Fruit cracking in litchi (*Litchi chinensis*): An overview. *Indian Journal of Agricultural Sciences* 87 (1): 03–11.

Mitra S K, Dutta Ray S K and Mandal D. (2014). Control of fruit cracking and sun-burning in litchi by irrigation and moisture conservation. *Acta Horticulturae* 1024:177–81.

Rani A, Lal R L, Uniyal S and Chand S. (2013). Response of organic manures on growth, nutrient status and yield of litchi *(Litchi chinensis* Sonn.) cv. Rose Scented. *Progressive Horticulture* 45(1): 126–31.

Yadav P, Lal R L and Pandey C. (2011). Effect of different levels of fertigation on yield, quality and leaf nutrient status of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. *Progressive Horticulture* 43(2): 276–80

Table- 1: Comparative variation in canopy humidity at different sprinkling hours (Anonymous 2000, 2001 and 2003)

Treatment	Average humidity (%)			
	Sprinkling hour			
	1.0	1.5	2.0	3.0
T_1	81.71(5.47 *)	85.83(10.79)	88.00(13.60)	91.90(18.62)
T_2	79.18(2.21)	80.18(3.50)	84.53(9.11)	87.41(12.83)
T_3	78.22(0.97)	78.62(1.48)	81.00(4.56)	85.34(10.16)
T_4	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_1	20.03	33.58	18.49	38.69	13.76	54.38	4.55	84.91
T_2	22.91	24.03	20.96	30.50	16.65	44.79	11.87	60.64
T_3	24.84	17.64	23.11	23.38	17.67	41.41	14.34	52.45
T_4	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 2000, 2001 and 2003

Table-3: Fruit biometrics under different treatments (Anonymous 2000, 2001 and 2003)

Treatment	Average length (mm)	Increment over Control (%)	Average breadth (mm)	Increment over control (%)
T_1	32.7	7.92	29.1	18.77
T_2	32.0	5.61	28.0	14.28
T_3	31.65	4.45	27.5	12.24
T_4	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 (Anonymous 2000, 2001 and 2003)

Treatment	Colour (Avg, point)	Taste (Avg. point)	Texture (Avg. point)	Overall mean	Remark
T_1	9.4	9.5	9.1	9.3	Excellent
T_2	9.2	9.0	9.1	9.1	Fine
T_3	8.8	8.5	8.9	8.73	Good
T_4	8.1	7.5	7.4	7.66	Satisfactory

Table-5: Average fruit yield under different treatments (Anonymous 2000, 2001 and 2003)

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_1	21.24	4.27	4.70	11.0	65.27	94.72
T_2	22.82	4.86	4.68	13.28	52.70	57.22
T_3	19.60	4.22	3.78	11.60	45.62	36.10
T_4	18.46	4.72	3.56	10.18	33.52	-
C.D. at 5%	5.7521	-	-	-	13.257	-
C.V.	9.1568	-	-	-	23.2567	-

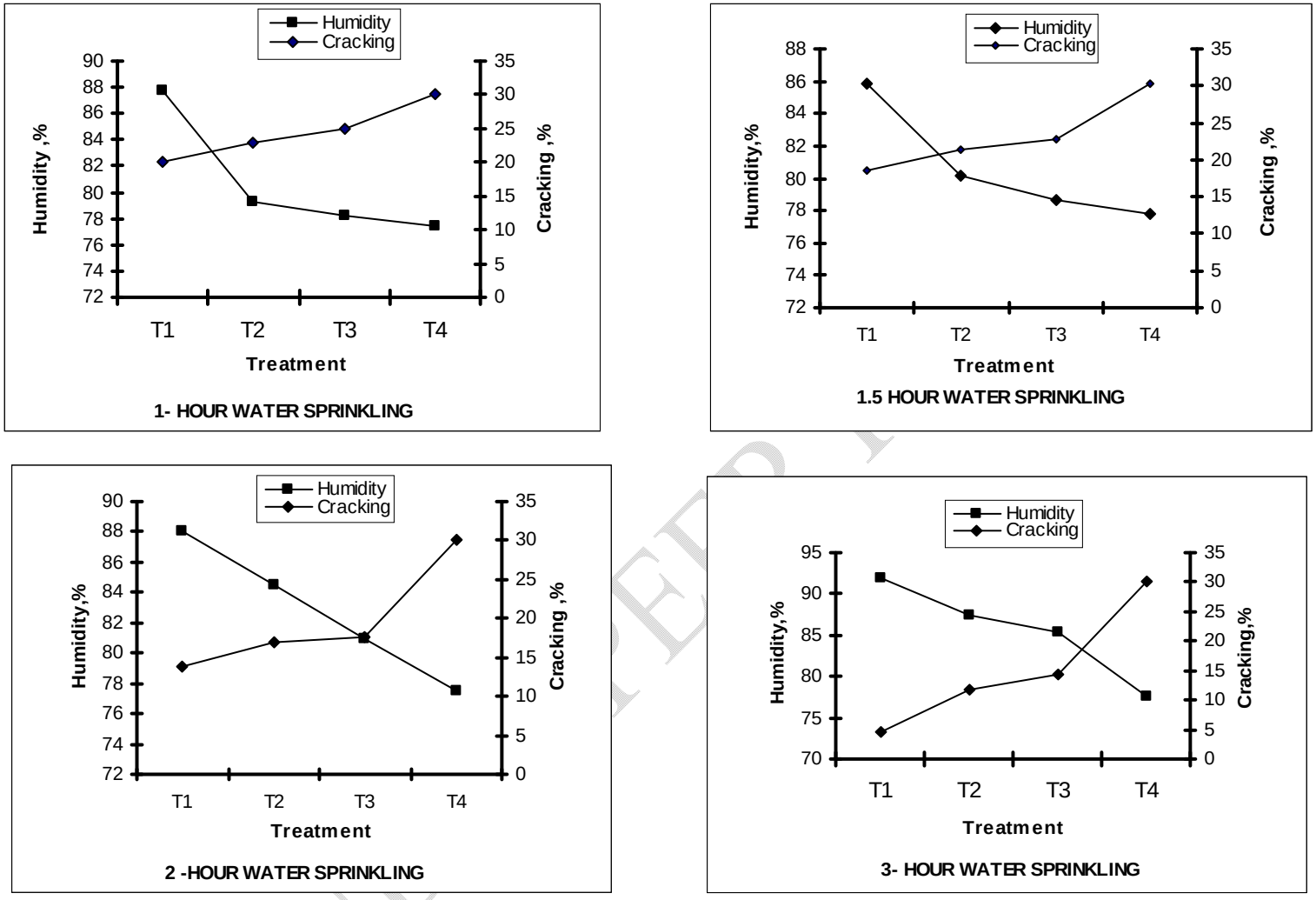

Figure –3: Effect of humidity on fruit cracking at different hours of water sprinkling over tree canopy

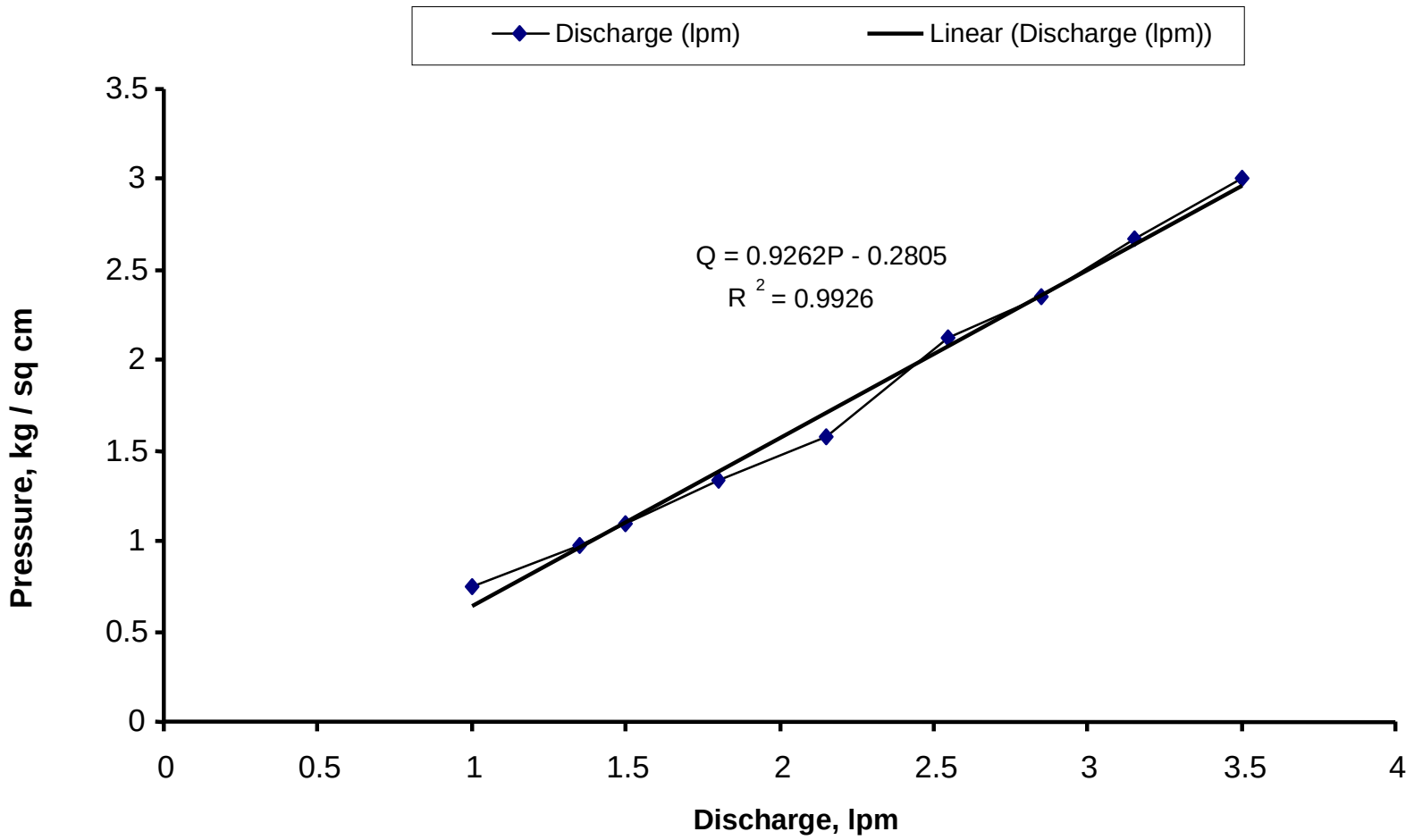

Fig-1: Relationship between discharge and pressure

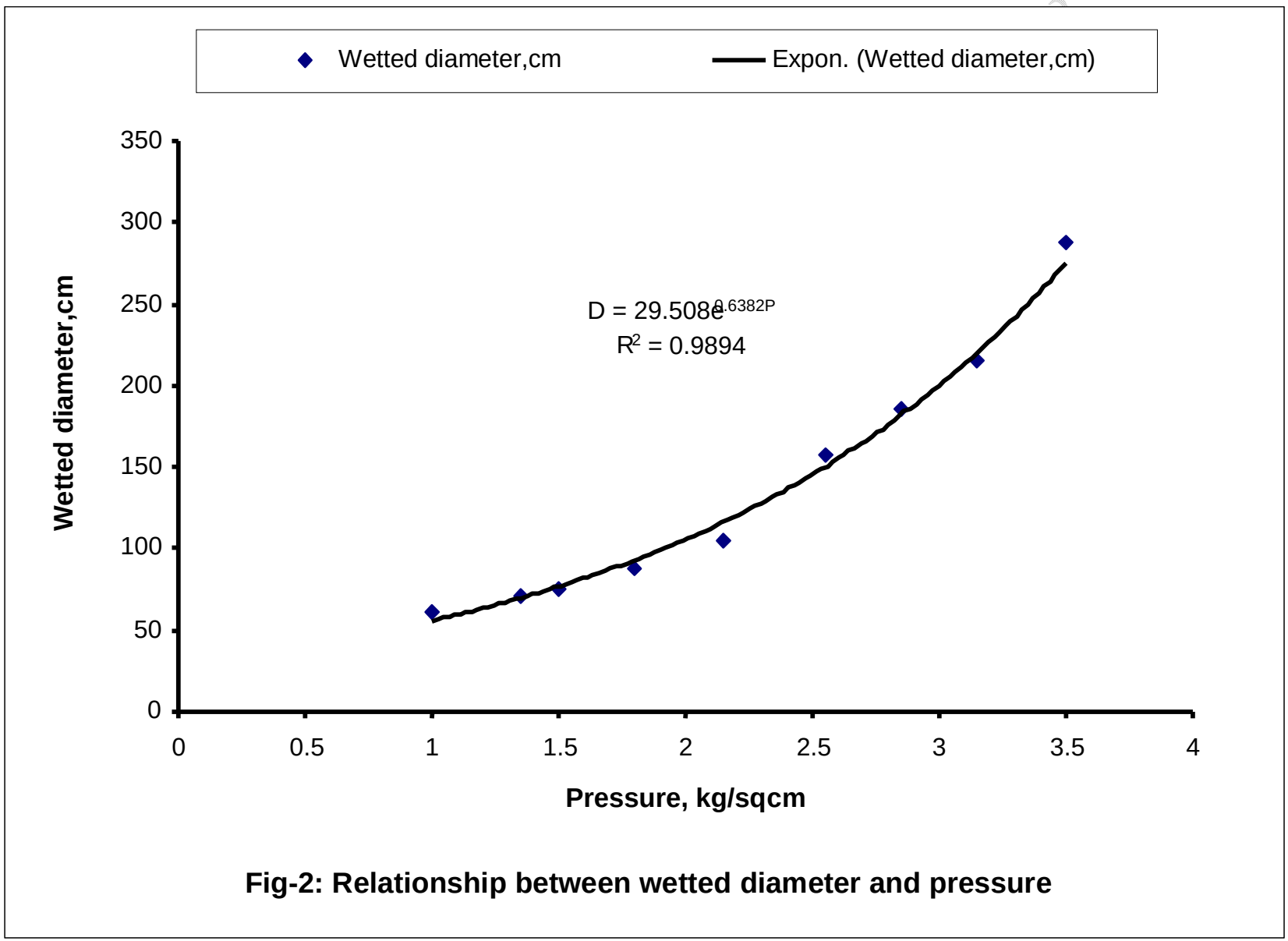

Fig-2: Relationship between wetted diameter and pressure