Indian J. Hort. 71(2), June 2014: 190-196

Studies on fertigation and soil application methods alongwith mulching on yield and quality of Assam lemon (*Citrus limon* L. Burmf.)

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ABSTRACT

A field experiment was conducted on alluvial sandy loam soils of Jorhat, Assam, India for three consecutive years (2010 to 2012) to evaluate the economical feasibility of fertigation and mulching on 4-year-old Assam lemon. The growth and yield of plants under 50 µm thick black plastic mulch was studied using four levels of fertigation applied at 120, 100 and 80% of recommended dose of fertilizer through drip. Soil application of fertilizers with recommended dose and no mulch was used for comparison and the results showed that 8.47 to 22.05% yield increase due to fertigation. Among the different fertigation levels, 120% of recommended dose with black plastic mulch gave the highest yield. The treatments with black plastic mulch showed 14.56 to 20.53% higher yield over non-mulched treatment. Highest net seasonal income of ₹ 2,31,644 per ha was obtained for the treatment, where 120% of recommended dose of fertilizer was applied through drip irrigation and lemon plants were mulched with black plastic mulch. However best benefit: cost ratio (4.17) was observed for the treatment where 80% of recommended dose of fertilizer was applied through fertigation and plants were not mulched. The fruit weight, volume and juice content studied during the experimentation showed significantly better results for lemon plants subjected to fertigation and black plastic mulching. The study revealed that fertigation can play a positive role in increasing productivity of Assam lemon with additional benefit of saving in fertilizer and labour cost and fruit quality improvement.

Key words: Assam lemon, drip irrigation, benefit cost ratio, mulches.

INTRODUCTION

North East India is one of the region of origin for citrus (Gmitter and Hu, 3). Assam lemon and Khasi mandarin are two important commercial citrus cultivars grown in North East India. Assam lemon (*Citrus limon* L. Burmf.) is native to Assam. Assam lemon is grown in an area of 13,000 ha in Assam with a productivity of 7.00 tonnes per ha. Assam lemon plants are evergreen in nature. They generally need ample supply of water and nutrient throughout the growing period. The crop is mainly grown as homestead dryland crop. Water deficit experienced during November-March in Assam severely affect its productivity and quality. In the recent years, attempts have been made for its commercialization, but, the efforts were severely handicapped by very little information on the drip irrigation and fertigation.

The studies on drip irrigation levels and mulch have reported to increase in yield (Kotoky *et al*., 4; Barua *et al.*, 1). Higher yield and quality production of citrus have been widely reported for other citrus crops like mandarins (Bettaga and Ben Mimoun, 2; Hasan and Sirohi, 4; Shirgure, 7; Shirgure *et al.*, 8; Shirgure *et al*., 9; Srivastava *et al.*, 10) but no work on fertigation levels with mulch has been done so far on Assam lemon. The present study was undertaken to standardize fertigation schedule for increasing yield and quality.

MATERIALS AND METHODS

An experiment was conducted at experimental farm of Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India (26º47´N latitude, 94º12´E and 86.8 msl) during 2010-2012. The soil of the experimental site consist of alluvial soil with sandy loam structure (69.6% sand, 9.4% silt, 21% clay), acidic reaction (pH 4.6), medium organic carbon (0.69%), medium in available nitrogen (282.84 kg/ha), available phosphorus (30.24 kg/ha) and potash (94.08 kg/ha). The treatments consisted of four levels of fertigations (*viz*. 120, 100, 80% of recommended doses of fertilizer (RDF) through fertigation and 100% of RDF through soil application) and two levels of mulches (*viz*. black plastic mulch of 50 µm thickness and no mulch). The annual recommended dose of fertilizer for Assam lemon is 600 N, 400 P_2O_5, 580 K_2O g per plant. The fertilizers were injected into the drip irrigation system through fertilizer injector. The nitrogen (N) was urea with mono ammonium phosphate (MAP), phosphorus with MAP and potash with muriate of potash was used. Concentration of N, P_2O_5 and K_2O in irrigation

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water was maintained within 250, 80 and 300 ppm, respectively.

Four-year-old Assam lemon plants grown at 3 m x 3 m spacing were subjected to the treatments for three consecutive years (2010-12). As per management practices all side branches upto 50-60 cm were removed keeping only single main trunk. Above 50-60 cm, pruning confined to the training. The eight treatments were replicated three times in a randomized block design.

The maximum water holding capacity of the soil of the experiment site was 14.2% and bulk density 1.56 g/cm^3. The quantity of water applied through drip irrigation along with fertilizer on a daily basis corresponded to replenishment of 80% of USWB class 'A' pan evaporation. Rainfall if any was deducted from the evaporation and rain in excess was discarded. The evaporation and rainfall data during the crop growth period are presented in Fig. 1. The evaporation was higher between April-September (3.0-3.3 mm) and the rainfall throughout the study period varied from 0 to 440 mm. Rainfall recorded in 2012 was higher by 75.6 and 27.84% compared to 2010 and 2011. The evaporation was also higher in 2012 by 4.5 and 20.9%, respectively.

For operating drip irrigation system, water was stored in a plastic water tank and subsequently pumped using a 0.5 hp centrifugal pump to maintain an operating pressure of 1 kg/cm^2 in the system. A separate drip lateral line of 12 mm size was laid for each row of crop. Each treatment consists of 3 rows of 9 plants. Two drippers of 2 lph (liters per h) capacity were provided for each plant. Drippers were placed at 30 cm on either side of the trunk. The emission uniformity of dripper discharge was maintained within 0.90-0.95. Fertilizers were applied after every fourth day with the help of a venturi injector. The dose of fertilizer application was distributed into 50 equal splits. The application of fertilizer through venturi was started in October and continued till April each year. Different doses of fertilizer were applied simultaneously through the venturi. Three rows were fertigated simultaneously for each fertigation treatment. The valves of other rows were closed during fertigation of plants of a particular treatment. The fertilizer amount to be applied for 27 plants of the treatment was added up for application of the fertilizer. Black LLDPE (linear low density polyethylene) film of thickness 50 µm was used for mulching. Mulch film cut to 2.25 m^2 size was used for each plant and the films were replaced every two years.

To evaluate the relative effectiveness of each treatment, data on growth attributes (plant height, stem girth and canopy diameter), yield and quality was recorded. The fruit quality assessment in terms of fruit weight, volume and juice content was done in the final year of the study only. The volume of the fruit was determined by water displacement method and expressed in cm^3. The juice content of the representative fruit sample was squeezed out and weighed.

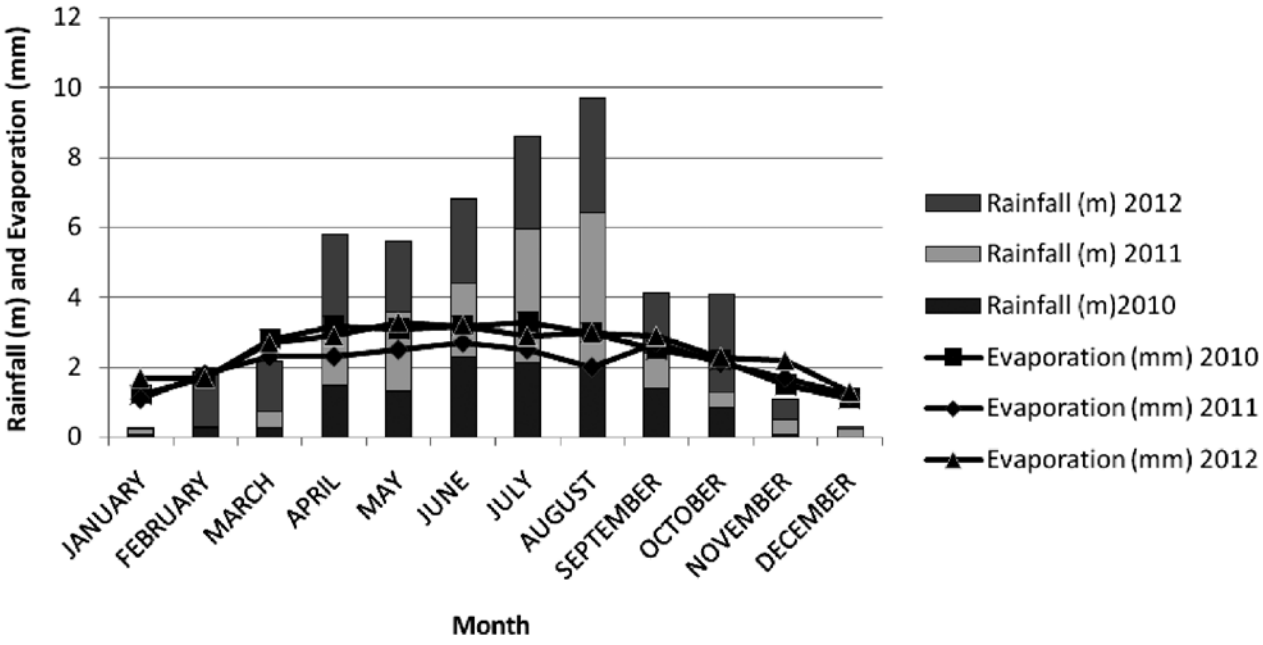

Fig. 1. Evaporation and rainfall during the crop growth period.

The economic feasibility was determined through benefit:cost analysis. The annualized cost of drip irrigation included depreciation, prevailing bank interest rate, repair and maintenance of the system. The interest rate and repair and maintenance cost of the system were 12 and 2% per annum of the fixed cost, respectively (Rao, 6). The useful life of drip system was considered to be 7 years. The cost of Assam lemon cultivation included expenses incurred in fertilizer, plastic mulch, and crop protection measures and harvesting. The benefit-cost ratio, the total cost of production and net return from growing Assam lemon in 1 ha plantation was then estimated (Table 3).

RESULTS AND DISCUSSION

Drip irrigation and fertigation with mulch induced significantly better plant growth (plant height, canopy diameter and stem girth) than soil application of fertilizer irrespective of different fertigation levels (*viz.* 120, 100 and 80% of RD). Fertigation ensured regular and adequate nutrient supply to the plants and that might have contributed to the higher plant growth of Assam lemon plants during these years (Table 1). The results clearly showed that even by 20% reduction (deficit) in fertilizer application through drip fertigation resulted in higher yield than that of soil application of fertilizer with 100% RDF, which is the conventional method of fertilizer application in the study area (Table 1). Fertigation with 120% of recommended dose has considerable influence on fruit yield in terms of number of fruits per plant (123.5) over the two other fertigation levels, *i.e.*, 100 (109.7) and 80% RDF (105.58) (Table 2). The highest yield was recorded as 139 fruit per plant in case of treatment with fertigation 120% RDF with plastic mulch followed by fertigaion with 100% RDF alongwith plastic mulch (135) (Table 1). Statistically Assam lemon yield in terms of number of fruits per plant was at par for fertigation levels of 100 and 80% RDF, which were found to be 11.2% and 14.5% lower than that of 120% RDF (Table 1).

The treatments with black plastic mulch, *i.e.* 'fertigation with 120% RDF and plastic mulch', 'fertigation with 100% RDF with plastic mulch', 'fertigation with 80% RDF with plastic mulch' and 'soil application100% RDF with plastic mulch' resulted in 19.82, 20.5, 19.0 and 14.5% higher yield, respectively, over fertigation at 120, 100 and 80% RDF and soil application of 100% RDF, respectively.

Analysis of variance study of fruit quality was done at the end of study period, *i.e.* in 2012 (Table 2). It revealed that both fertilizer application and mulching significantly influenced individual fruit weight, fruit volume and juice content of Assam lemon. Better quality fruits resulted from higher fertigation doses and from mulched plants. The combined effect of fertigation and mulching was also significant for all the quality parameters. Highest yield (14.8 t/ha), highest individual fruit weight (108.4 g) , highest fruit volume (105.5 cm^3) was observed in the treatment where plants were fertigated with 120% of recommended dose of fertlizer and mulched. However, highest juice content (43.01%) was observed when the plants were fertigated with 100% of recommended dose of fertilizer with plastic mulch.

The economic analysis and water productivity of Assam lemon production from 1 ha area was done (Table 3). The net seasonal income was found to be highest (₹ 2,31,644 /ha) in fertigation with 120% of recommended dose (fertigation 120% RDF with plastic mulch) followed by treatment 'fertigation 100% RDF with plastic mulch' (₹ 2,24,978). The highest benefit-cost ratio of 4.17 was obtained for fertigation with 80% of recommended dose followed by 3.51 (with fertigation at 100% RDF). The highest water use efficiency (WUE) of 397.74 kg /ha-mm was recorded in the treatment where 120% of recommended dose of fertilizer was given through fertigation and the plants were mulched with black plastic. The highest fertilizer use efficiency of 26.6, 39.9 and 27.5, respectively for N, P and K fertilizers was observed in the treatment where 80% of recommended dose of fertilizer was met through fertigation black plastic mulch. Similar results were reported for drip fertigated acid lime (Shirgure *et al.*, 8; Shirgure *et al.*, 9) and mandarin (Srivastava *et al.*, 10).

Based on the results of the experiment carried and subsequent economic analysis for young Assam lemon plantation, it may be concluded that among the different fertilizer application levels, 80% of recommended dose of fertilizer applied through drip fertigation resulted in the maximum return on investment with B:C ratio of 4.17. Plastic mulch use did not result in better returns, however, in terms of yield and WUE it was maximum where 120% of recommended dose of fertilizer was applied through fertigation and black mulched plastic. The yields increase due to use of drip irrigation and fertigation over conventional soil application ranged from 6.7 to 17.8%.

ACKNOWLEDGEMENT

Authors are thankful to the Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India for providing funds under the project "Horticulture Mission for North East and Himalayan States, MM-1".

Table 1. Plant growth as influenced by fertigation levels and mulching.

Treatment	Plant height (m)	Canopy diameter (m)	Stem girth (cm)	Yield (No. of fruits per plant)
		2010		
T1	1.57	2.68	5.70	110
T2	1.54	2.67	5.30	102
T3	1.55	2.33	5.50	93
T4	1.30	2.36	2.90	93
T5	1.56	2.66	5.61	100
T6	1.53	2.34	5.81	102
T7	1.56	2.52	5.52	103
T8	1.31	2.17	2.92	95
$CD_{0.05}$	0.07	0.23	0.89	NS
		2011		
T1	1.94	2.76	15.50	151
T2	1.86	2.71	14.75	149
T3	1.91	2.68	14.00	130
T4	1.62	2.45	9.50	152
T5	1.92	2.72	15.51	110
T6	1.84	2.68	15.52	112
T7	1.89	2.65	16.10	124
T8	1.59	2.48	10.23	100
$CD_{0.05}$	0.08	0.26	3.76	10.01
		2012		
T1	2.03	2.66	29.25	155
T2	1.94	2.53	27.25	148
T3	1.99	2.55	26.00	151
T4	1.65	2.24	19.25	134
T5	2.02	2.50	27.00	123
T6	1.93	2.49	33.25	121
T7	1.98	2.50	28.75	119
T8	1.64	2.19	18.25	107
$CD_{0.05}$	0.07	0.15	0.32	2.60
Mean	1.73	2.52	14.90	121.26
		Pooled		
T1	1.92	2.65	20.53	139
T2	1.85	2.58	20.50	135
T3	1.90	2.59	20.38	131
T4	1.59	2.31	16.75	118
T5	1.91	2.62	20.25	116
T6	1.84	2.55	20.23	112
T7	1.89	2.53	20.11	110
T8	1.58	2.28	16.48	103
$CD_{0.05}$	0.09	0.07	0.12	15.15

T1, T2, T3 = Fertigation with 120, 100 and 80% RDF and black plastic mulch, T5, T6, T7 = Fertigation with 120, 100 and 80% RDF and no mulch, T4 = Soil application of fertilizer 100% RDF and black plastic mulch, T8 = Soil application of fertilizer 100% RDF and no mulch.

Table 2. Effect of fertigation and mulch on fruit yield and quality during 2010-12.

Yield and quality parameter	Fertilizer application → / Mulching ↓	Fertigation 120% RDF	Fertigation 100% RDF	Fertigation 80% RDF	Soil application 100% RDF	Mean
Yield (No. of fruits/ plant)	Plastic mulch	123.52	109.71	105.58	95.44	108.77
	No mulch	80.66	79.24	72.43	59.63	73.07
	Mean	104.15	96.97	88.69	93.67	
	$CD_{0.05}$			A. Effect of fertilizer application level =		7.43
				B. Effect of mulching =		9.11
				A × B =		12.88
Yield (t/ha)	Plastic mulch	14.88	12.65	11.06	10.01	12.15
	No mulch	8.05	7.63	6.40	7.73	7.45
	Mean	11.47	10.14	8.73	8.87	
	$CD_{0.05}$			A. Effect of fertilizer application level =		3.13
				B. Effect of Mulching =		4.42
				A × B =		6.25
Fruit weight, (g)	Plastic mulch	108.43	101.67	97.67	94.40	100.54
	No mulch	89.83	86.67	79.53	76.07	83.00
	Mean	99.13	94.12	88.60	85.23	-
	$CD_{0.05}$			A. Effect of fertilizer application level =		1.65
				B. Effect of mulching =		2.34
				A × B =		3.30
Fruit volume (cm^3)	Plastic mulch	105.50	99.03	95.30	92.07	97.98
	No mulch	86.87	83.70	76.50	75.07	80.53
	Mean	96.18	91.37	85.90	83.57	-
	$CD_{0.05}$			A. Effect of fertilizer application level =		1.68
				B. Effect of mulching =		2.38
				A × B =		3.37
Juice content (%)	Plastic mulch	42.62	43.01	42.83	40.61	42.35
	No mulch	42.35	39.84	41.52	41.43	41.37
	Mean	42.57	41.52	42.23	41.13	
	$CD_{0.05}$			A. Effect of fertilizer application level =		0.006
				B. Effect of mulch =		0.009
				A × B =		0.013

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Table 3. Comparative economics, water and fertilizer use efficiency of drip fertigation and plastic mulch in Assam lemon (pooled data).

Sl. No.	Treatment / Parameter	Fertigation 120% RDF + PM	Fertigation 100% RDF + PM	Fertigation 80% RDF + PM	Soil application 100% + PM	Fertigation 120% RDF	Fertigation 100% RDF	Fertigation 80% RDF	Soil application 100% RDF
1.	Fixed cost (₹)	35,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000
	A) Life (yrs)	10	10	10	10	10	10	10	10
	B) Depreciation (₹)	3,500	3,500	3,500	3,500	3,500	3,500	3,500	35,00
	C) Interest (12%) (₹)	4,200	4,200	4,200	4,200	4,200	4,200	4,200	42,00
	D) Repair and maintenance (7% of initial cost) (₹)	2,450	2,450	2,450	2,450	2,450	2,450	2,450	2,450
	Total (B + C + D)	10,150	10,150	10,150	10,150	10,150	10,150	10,150	10,150
2.	Cost of cultivation								
	a) Cost of mulching, ₹ (annualized)	14,000	14,000	14,000	14,000	0	0	0	0
	b) Fertilizer (₹)	35,052	29,210	23,296	35,141	35,052	29,210	23,296	35,141
	c) Other costs (₹)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	4,000
	Total a + b + c (₹)	51,052	45,210	39,296	51,141	37,052	31,210	25,296	39,141
3.	Seasonal total cost (1 + 2) (₹)	61,202	55,360	49,446	61,291	47,202	41,360	35,446	49,291
4.	Yield (No. of fruits) ('000/ha)	154	150	146	131	129	124	122	114
5.	Selling price (₹/1000 fruit) (₹)	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
6.	Income from produce (₹/ha) (4-5)	2,31,644	2,24,978	2,18,312	1,96,647	1,93,314	1,86,648	1,83,315	1,71,650
7.	Net seasonal income (6-3) (₹)	170,442	169,618	168,866	135,356	146,112	145,288	147,869	122,359
8.	Benefit: cost ratio	2.78	3.06	3.42	2.21	3.10	3.51	4.17	2.48
9.	Water used (mm)	42.10	42.10	42.10	42.10	42.10	42.10	42.10	42.10
10.	Fruit wt. (g)	108.43	101.67	97.67	94.40	89.83	86.67	79.53	76.07
11.	WUE (water use eff.) (kg/ha-mm)	397.74	362.21	337.65	293.96	274.99	256.16	230.86	206.77
12.	Fertilizer used (kg)								
	N	799.92	666.60	533.28	666.60	799.92	666.60	533.28	666.60
	P	533.28	444.40	355.52	444.40	533.28	444.40	355.52	444.40
	K	773.26	644.38	515.50	644.38	773.26	644.38	515.50	644.38
13.	Fertilizer use efficiency (kg/kg)								
	N	20.93	22.88	26.66	18.57	14.47	16.18	18.23	13.06
	P	31.40	34.31	39.98	27.85	21.71	24.27	27.34	19.59
	K	21.65	23.66	27.57	19.21	14.97	16.74	18.85	13.51

RDF = Recommended dose of fertilizer, PM = Plastic mulch

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Received: July, 2013; Revised: March, 2014;
Accepted: April, 2014