

Yield, fruit quality and water productivity of drip fertigated Assam Lemon (*Citrus limon*)

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■ **ABSTRACT** : Yield, fruit quality, economic feasibility and water productivity of 4 years old Assam lemon plants were evaluated through a field experiment conducted on old alluvial sandy loam soils of Jorhat, Assam, India for 3 consecutive years (2010 to 2012). Four levels of fertilizer application *i.e.* 120%, 100% and 80% of recommended dose of fertilizer through drip-fertigation and 100% recommended dose of fertilizer through soil application with 50 μ m thick black plastic film mulching was studied through a 4x2 factorial experiment in RBD. Results showed significant yield increase due to drip fertigation. Yield and quality of fruit varied with fertigation level and higher doses resulted in better values. WUE and water productivity also varied with fertigation levels in mulched treatments. Best benefit to cost ratio and fertilizer use efficiency was observed for the treatment where 80% of recommended dose of fertilizer was applied through drip-fertigation and plants were not mulched. The study reveals that drip-fertigation can play a positive role in increasing yield, WUE and water productivity of Assam lemon plants with additional benefit of saving in fertilizer cost, fruit quality improvement and better return on investment.

■ **KEY WORDS** : Assam Lemon, Benefit cost ratio, Drip-fertigation, Water productivity

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North East India is one of the places of origin for citrus (Gmitter and Hu, 1990). Assam lemon and Khasi Mandarin are two important commercial citrus fruit of North East India. Assam lemon (*Citrus limon* L. Burmf) is native to Assam, a state in the North East India. It is the main source of vitamin C in the diet of common people. The fruit lemons are normally consumed raw. They are also used for preparation of refreshing drinks and pickles as well as garnishing curry preparations.

Assam lemon plants are evergreen in nature. They generally need ample supply of water and nutrient throughout the year. The crop is mainly grown as homestead dryland crop. Water deficit experienced during November to March in Assam severely affects its productivity. In the recent years, attempts have been made for its commercialization, but, the efforts were severely handicapped by very little information on the irrigation and fertigation aspects. Two studies on drip irrigation reported increase in yield (Kotoky *et al.*, 2005; Barua *et al.*, 2000). Higher yield and reduction of production cost have been widely reported for other citrus crop while using drip fertigation (Srivastava *et al.*, 2003; Shirgure,

2012) but no work on fertigation has been done so far on Assam lemon. This study was undertaken to evaluate feasibility of drip fertigation for growing Assam lemon crop profitably.

■ METHODOLOGY

The experiment was conducted at experimental farm of Department of Horticulture, Assam Agricultural University, Jorhat, Assam, India (26°47'N latitude, 94°12'E and 86.8 m elevation) for 3 years (2010-2012). The soil of the experimental site consisted of old 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 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 fertilizer application (*viz.*, 120%, 100%, 80% of recommended doses of fertilizer (RD) through fertigation and 100% of RD through soil application) and two levels of mulch (*viz.*, black plastic mulch of 50 μ m thickness and no mulch). The recommended dose of fertilizer was 600g N, 400g P and 580g K per plant per year. Nitrogen

as urea and MAP (Mono ammonium phosphate, MAP), phosphorus as MAP and potash as muriate of potash were injected into the drip irrigation system at 3 days interval through fertilizer injector. Concentration of N, P and K in irrigation water was maintained within 250, 80 and 300 mg/l, respectively.

Four years old Assam Lemon plants grown at 3Mx3M spacing were subjected to the treatments for three consecutive years (2010-12). As per management practices all side branches upto 50-60cm were removed keeping only single main trunk. Above 50-60 cm, pruning confined to the training to develop. The 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 kg/m³. The quantity of water applied through drip irrigation along with fertilizer corresponded to replenishment of 80% of USWB class 'A' pan evaporation on a daily basis. Rainfall if any was deducted from the evaporation and rain in excess was disregarded. Contribution from ground water was discounted because of low ground water table prevalent during the experiment. The evaporation and rainfall data during the crop growth period are presented in Fig.A. The evaporation was higher between April to September (3.0-3.3 mm) and the rainfall throughout the study period varied from 0 to 440 mm. Rainfall recorded in the year 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.

The drip irrigation system used was connected to an overhead tank. An operating pressure of 1 kg/cm² was maintained. A separate drip lateral line of 12mm size was laid for each row of crop. Each treatment consisted of 3 rows with 9 plants in each row. Two drippers of 2 l/h capacity were provided for each plant. Drippers were placed at 30 cm on either side of the trunk. The uniformity coefficient of dripper discharge was maintained within 0.90-0.95. Black LLDPE (linear low density polyethylene) film of thickness 50µm was used for mulching. Mulch film cut to 2.25 m² size was used for each plant and the films were replaced in every two years.

To evaluate the relative effectiveness of each treatment, data on yield attributes (plant height, stem girth and canopy diameter) and yield were recorded. The fruit quality assessment in terms of individual fruit weight, fruit volume, titratable acidity, total soluble solids (TSS) and ascorbic acid was done in the final year of the study only. The volume of the fruit was determined by water displacement method and expressed in cm³. TSS of the fruit samples were determined by Zeiss hand juice Brix refractometer and the results were expressed in °Brix. Ascorbic acid content was estimated by the visual titration method of Freed (1966).

The economic feasibility was determined through benefit-cost analysis based on three years pooled data. The annualized cost of drip irrigation includes 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, 1994). The useful life of drip system was considered to be 7 years. The cost of Assam lemon cultivation includes expenses incurred in fertilizer, plastic mulch, crop protection measures and harvesting. Water and fertilizer use efficiency was estimated by dividing yield (kg/ha) by seasonal cumulative water use (mm) and fertilizer use (kg/ha), respectively.

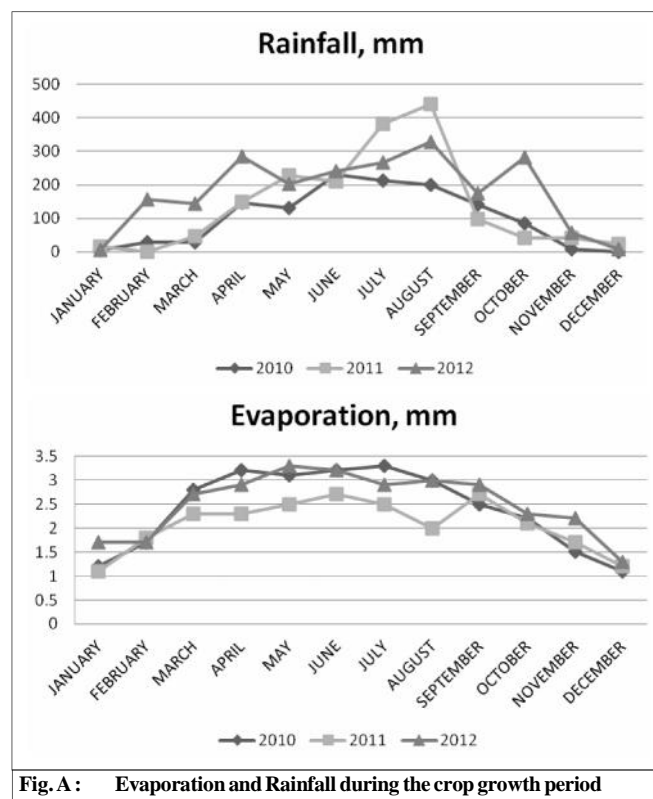


Fig. A: Evaporation and Rainfall during the crop growth period

RESULTS AND DISCUSSION

Drip fertigation induced significantly better plant growth (plant height, canopy diameter and stem girth) (at 5% level) than soil application of fertilizer irrespective of different fertigation levels (*viz.*, 120%, 100% and 80% of RD). Black plastic mulch failed to influence the plant growth significantly. Fertigation ensured regular and adequate nutrient supply to the plants and that might have contributed to the higher plant growth of Assam lemon plants in these years (Table 1). The results clearly showed that even 20% reduction (deficit) in fertilizer doses through fertigation resulted in higher yield than conventional fertilizer application (soil application with 100% recommended

doses) (Table 2 and 3). Fertigation @120% of recommended dose has considerable influence on Assam lemon yield in terms of number of fruits per plant (136.66 numbers per plant) over the two other fertigation levels, that is, 100% RD (121.38 numbers per plant) and 80% RD (116.83 numbers per plant) (Table 2) . The highest yield was recorded as 139 numbers per plant in case of treatment ‘Fertigation

120% RD + PM’ followed by ‘Fertigation 80% RD + PM’ (135 numbers per plant) (Table 3). Statistically Assam Lemon yield in terms of number of fruits per plant was at par for fertigation level of 100% RD and 80% RD, which were found to be 11.18 % and 14.51 % lower than that of 120% RD. Increase in number of fruits may be attributed to frequent fertigation that lowered the soil water suction facilitating

Table 1 : Yield attribute as influenced by fertigation level and mulches in Assam lemon

Parameters (year wise and pooled)	A. Fertilizer levels				Soil application 100% RD	CD 0.5	B. Mulching		CD 0.5	Interaction (CD=0.5) 1=Ax B 2=Ax Year 3=Bx Year 4=AxBxYear
	Fertigation			Non mulch			Plastic mulch (PM)			
	120% RD	100% RD	80% RD							
Plant height (m)										
2010	1.65	1.59	1.62	1.10	0.08	1.49	1.49	NS	NS	
2011	2.03	1.88	1.98	1.39	0.10	1.80	1.84	NS	NS	
2012	2.15	1.97	2.08	1.39	0.08	1.89	1.91	NS	NS	
Pooled	2.04	1.88	1.98	1.35	0.59	1.80	1.82	NS	NS	
Canopy diameter (m)										
2010	2.59	2.47	2.47	1.86	0.14	2.36	2.35	NS	1	
2011	2.85	2.76	2.70	2.22	0.11	2.60	2.67	NS	1	
2012	2.71	2.56	2.59	1.98	0.11	2.41	2.51	NS	NS	
Pooled	2.75	2.62	2.62	2.07	0.07	2.48	2.55	0.05	2,3	
Stem girth (m)										
2010	5.57	5.52	5.77	2.92	0.48	4.98	4.93	NS	NS	
2011	16.31	17.77	17.52	11.10	2.17	15.49	15.86	NS	NS	
2012	30.28	28.91	28.54	19.28	2.41	26.34	27.16	NS	NS	
Pooled	21.39	21.33	21.09	13.82	1.42	19.14	19.67	NS	NS	

NS=Non-significant

Table 2 : Yield (number of fruits per plant) as influenced by fertigation level and mulches in Assam lemon

Factor	2010	2011	2012	Pooled
Fertilizer application				
Fertigation 120% RD	105.00	151.50	153.50	136.66
Fertigation 100% RD	102.50	127.33	135.33	121.38
Fertigation 80% RD	98.16	125.33	128.83	116.83
Soil application 100% RD	94.50	104.33	113.50	107.11
Mulching				
Black plastic mulch	100.25	132.16	133.83	130.08
Non mulched	99.83	123.00	131.75	110.91
CD_{0.5}				
A	NS	20.85	23.36	7.43
B	NS	NS	NS	9.11
AB	NS	NS	NS	12.88
C				10.51
AC				NS
BC				NS
ABC				25.76
CV	10.60	13.20	14.21	13.01

NS=Non-significant

Table 3 : Treatment and year wise yield (number of fruits per plant) of Assam Lemon

Treatments		Year wise yield (number of fruits per plant)			
		2010	2011	2012	Pooled
Fertigation 120 % RD + PM	T ₁	110.20	151.34	155.70	139.33
Fertigation 100 % RD + PM	T ₂	102.51	149.85	148.08	135.68
Fertigation 80 % RD + PM	T ₃	93.12	130.65	151.19	131.47
Soil application 100% RD+PM	T ₄	93.10	152.41	134.32	118.57
Fertigation 120 % RD	T ₅	100.86	110.25	123.64	116.75
Fertigation 100 % RD	T ₆	102.02	112.84	121.17	112.32
Fertigation 80% RD	T ₇	103.05	124.30	119.27	110.06
Soil application 100% RD	T ₈	95.21	100.69	107.21	103.74
	CD _{0.05}	NS	10.01	2.66	15.15
	CV	10.00	13.32	14.10	13.23

NS=Non-significant

Table 4 : Effect of different fertigation level and mulching on fruit quality of Assam lemon

Fruit quality	Fertilizer application ↓ Mulching →	Fertigation			Soil application	Mean
		120% RD	100% RD	80% RD	100% RD	
Fruit weight, g	Plastic mulching	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	-
					S.E±	C.D. (P=0.05)
	A. Effect of fertilizer application level				0.77	1.65
	B. Effect of mulching				1.09	2.34
	A X B			1.54	3.30	
Fruit volume , ml	Plastic mulching	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	-
					S.E±	C.D. (P=0.05)
	A. Effect of fertilizer application level				0.78	1.68
	B. Effect of mulching				1.11	2.38
	A X B			1.67	3.37	
TSS, °Brix	Plastic mulching	8.37	8.10	7.87	7.23	7.89
	No mulch	8.00	7.77	7.33	6.57	7.42
	Mean	8.18	7.93	7.60	6.90	-
					S.E±	C.D. (P=0.05)
	A. Effect of fertilizer application level				0.07	0.16
	B. Effect of mulching				0.11	0.23
	A X B			0.15	0.32	
Titrateable Acidity ,%	Plastic Mulching	3.13	3.40	3.90	4.23	3.67
	No Mulch	3.60	3.90	4.50	5.40	4.35
	Mean	3.37	3.65	4.20	4.82	-
					S.E±	C.D. (P=0.05)
	A. Effect of fertilizer application level				0.08	0.18
	B. Effect of mulching				0.11	0.25
	A X B			0.16	0.36	
Ascorbic acid, mg/100ml	Plastic mulching	52.13	46.77	43.5	45.83	47.06
	No mulch	43.3	41.43	41.07	39.33	41.28
	Mean	47.72	44.1	42.28	42.58	-
					S.E±	C.D. (P=0.05)
	A. Effect of fertilizer application level				0.47	1.02
	B. Effect of mulching				0.67	1.44
	A X B			0.95	2.04	

Table 5: Comparative economics, water and fertilizer use efficiency of drip fertigation with and without plastic mulch in Assam lemon (based on three years pooled data)

Sr. No.	Parameters	Treatments					Soil application 100% +PM	Soil application 100% RD	Soil application 80% RD	Soil application 100% RD	Soil application 100% RD				
		Fertigation 120% RD +PM	Fertigation 100% RD+PM	Fertigation 80% RD +PM	Fertigation 100% RD	Fertigation 120% RD						Fertigation 80% RD	Fertigation 100% RD		
1.	Fixed cost, ₹	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
	Life (yrs)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Depreciation, ₹	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
	Interest (12%), ₹	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
	Repair and maintenance (7% of initial cost), ₹	2450	2450	2450	2450	2450	2450	2450	2450	2450	2450	2450	2450	2450	2450
	Total (B+C+D)	10150	10150	10150	10150	10150	10150	10150	10150	10150	10150	10150	10150	10150	10150
2.	Cost of cultivation														
	Cost of mulching, ₹ (annualized)	14000	14000	14000	14000	14000	14000	14000	0	0	0	0	0	0	0
	Fertilizer, ₹	35052	29210	23296	23296	35141	35141	29210	35052	29210	23296	23296	23296	35141	35141
	Other cost, ₹	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	Total a+b+c, ₹	51052	45210	39296	39296	51141	51141	31210	37052	31210	25296	25296	25296	35141	35141
3.	Seasonal total cost (1+2), ₹	61202	55350	49446	49446	61291	61291	41360	47202	41360	35446	35446	35446	49291	49291
4.	Yield (no. of fruits) (000/ha)	154	150	146	146	131	131	124	129	124	122	122	122	114	114
5.	Selling price (₹s/1000 fruit), ₹	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500	1500
6.	Income from produce (Rs/ha) (4*5) ₹	231644	224978	218312	218312	196647	196647	186648	193314	186648	183315	183315	183315	171650	171650
7.	Net seasonal income (6-3), ₹	170442	169618	168866	168866	135356	135356	145288	146112	145288	147869	147869	147869	122359	122359
8.	Benefit cost ratio	2.78	3.06	3.42	3.42	2.21	2.21	3.51	3.10	3.51	4.17	4.17	4.17	2.48	2.48
9.	Water used (mm)	42.10	42.10	42.10	42.10	42.10	42.10	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	97.67	94.40	94.40	89.83	89.83	86.67	79.53	79.53	79.53	76.07	76.07
11.	WUE (Water use Eff.) (kg/ha-mm)	397.74	362.21	337.65	337.65	293.96	293.96	256.16	274.99	256.16	230.86	230.86	230.86	206.77	206.77
12.	Fertilizer used (kg)														
	N	799.92	666.60	533.28	533.28	666.60	666.60	666.60	799.92	666.60	533.28	533.28	533.28	666.60	666.60
	P	533.28	444.40	355.52	355.52	444.40	444.40	444.40	533.28	444.40	355.52	355.52	355.52	444.40	444.40
	K	773.26	644.38	515.50	515.50	644.38	644.38	644.38	773.26	644.38	515.50	515.50	515.50	644.38	644.38
13.	Fertilizer use efficiency (kg/kg)														
	N	20.93	22.88	26.66	26.66	18.57	18.57	16.18	14.47	16.18	18.23	18.23	18.23	13.06	13.06
	P	31.40	34.31	39.98	39.98	27.85	27.85	24.27	21.71	24.27	27.34	27.34	27.34	19.59	19.59
	K	21.65	23.66	27.57	27.57	19.21	19.21	16.74	14.97	16.74	18.85	18.85	18.85	13.51	13.51

better uptake of moisture and nutrients by the plants.

The treatments with plastic mulch (T₁, T₂, T₃ and T₄) resulted 19.82, 20.53, 19.09 and 14.56 % higher yield, respectively over non mulched treatments (T₅, T₆, T₇ and T₈) (Table 2). It clearly revealed that under deficit fertigation, mulching effect became more prominent. However, pooled analysis of three years data showed the effect of black plastic to be non-significant for yield.

Analysis of variance study of fruit quality was done at the end of study period *i.e.* in 2012 and shown in Table 4. Fertigation resulted in increase in fruit volume (96.18 cc), fruit weight (99.13 g), TSS (8.18 %) and ascorbic acid (47.72mg /100 ml) content but reduction in titratable acidity (3.37 %). The reduction of acidity might be due to the dilution effect with the increase in moisture content. Black plastic mulching was also able to increase fruit volume, fruit weight, TSS, and ascorbic acid content significantly. Overall better quality fruits resulted from higher fertigation doses and from mulched plants. The interaction effect of fertigation and mulching was also significant for all the quality parameters.

Table 5 presents the economic analysis and water productivity of Assam lemon production from 1 ha area. The net seasonal income was found to be highest (Rs. 170442 per ha) in fertigation with 120% of recommended dose but highest benefit-cost ratio (4.17) was obtained for fertigation with 80% of recommended dose. The highest WUE (water use efficiency) (397.74 kg /ha-mm), was recorded in the treatment where 120% of recommended dose of fertilizer was met through fertigation and the plants were mulched with black plastic mulch. This is mainly because of higher fruit yield obtained through fertigation. The highest fertilizer use efficiency of 26.66, 39.98 and 27.57, respectively for N, P and K fertilizer was observed in the treatment where 80% of recommended dose of fertilizer was met through fertigation and the plants were mulched with black plastic mulch.

Conclusion :

Drip fertigation resulted in higher yield and better

quality of Assam Lemon fruits. A reduced dose (*i.e.* 80% of recommended dose of fertilizer applied through drip fertigation) resulted in getting the maximum return on investment with B:C ratio of 4.17. Plastic mulch use did not significantly influenced yield but was able to enhance quality significantly. However, in terms of yield, WUE and water productivity it was maximum where 120 % of recommended dose of fertilizer was applied through drip fertigation and the plants were mulched with black plastic mulch.

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