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Integration of rain water harvesting and drip irrigation for increasing productivity of lemon [*Citrus limon* (L.) Burmf)

PANKAJ BARUA

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Correspondence to:
PANKAJ BARUA
Department of Agricultural Engineering, Assam Agricultural University, JORHAT (ASSAM) INDIA
Email: pankaj_barua2001@yahoo.com

ABSTRACT : An experiment on integration of rainwater harvesting with drip irrigation to increase productivity of lemon was conducted at Assam Agricultural University, Jorhat, Assam during 2009 to 2011. Rainwater harvested in plastic film lined pond during *Kharif* season was utilized to irrigate plants of lemon grown at 3 m x 3m spacing using drip irrigation with three levels during *Rabi*. Black plastic mulch was used as an additional water saving technique. The irrigation levels tested were 1.0, 0.8 and 0.6 times of pan evaporation *(*PE) measured by a USDA Class-A pan. Two years old lemon plants were subjected to the treatments for three consecutive years. The harvested water was monitored for yield and quality. Crop yield and quality, water use and economic analysis were carried out. The analysis of year wise as well as pooled data on plant height, canopy diameter, stem girth, and yield in terms of number of fruits per plant revealed that only drip irrigation irrespective of different levels significantly influenced the observed parameters. Black plastic did not significantly influence growth and yield of lemon. The economic analysis revealed that the integration of rainwater harvesting and drip irrigation was a viable option for increasing productivity and quality of lemon fruits at BCR (benefit to cost ratio) of 2.33.

KEY WORDS : Lemon, Drip irrigation, Rain water harvesting

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Water is in scarcity. Increasing demand from industrial and domestic sector is likely to reduce the water available for agriculture in near future. It is ,therefore, a valid concern of scientist and policy makers as to how to meet the increasing demand from industry and domestic sector while at the same time catering for the ever increasing demand from agriculture. The problem has become more acute as there are little or no additional water sources for further development. Good water management may be viable option. There have been considerable advances in this area through improved technology and cultivation practices. Indian subcontinent on an average receives high monsoon rainfall for about four months. However, remaining months remain mostly dry. Therefore, rain water harvesting may be a viable option in India. The concept of rainwater harvesting is not new in India. The country has a long tradition of water harvesting. But unfortunately many of the traditional water harvesting system have either fallen into disuse due to variety of physical, social, economic and cultural and political factors which have caused their deterioration, decline of institutions which has nurtured them (Agarwal and Narain , 1997) or have lost their relevance in the modern day context due to their inability to meet the desires of the community. While the first dimension of decline in water harvesting tradition has been well researched and documented, the second dimension is much less understood and appreciated (Kumar *et al.*, 2006). Water harvesting itself may not provide adequate tangible benefit to the community to sustain interest in it in modern day context. There is a need for integration of water harvesting with appropriate technology for judicious use of the water so harvested and also to create interest among the stakeholders. The research reported here was an effort in this direction.

Although Assam receives high rainfall in the tune of 1954 mm per annum (Anonymous, 2004) its distribution is erratic. Most of the rainfall occurs during the months of May to August. The remaining months *i.e.* October to April are virtually dry with only 2-3 per cent of the total rainfall interception. Therefore, crop suffers from moisture stress that results in reduction in productivity and quality of produce and sometimes both. Harvesting of rain-water during *Kharif* and using it during *Rabi* for increasing productivity is a possibility. But harvesting rainwater involves cost and thus water so harvested needs to be utilized efficiently through appropriate technology. Drip irrigation has established itself

as a useful technology for efficient water management.

Lemon [*Citrus limon* (L.) Burmf] is a major citrus fruit of Assam and 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. Lemon grown on a fairly large scale in Assam mostly as rain fed crop. The erratic distribution of rainfall leads to significantly depletion of soil water during growing season of the lemon plants. Production is, therefore, not up to the mark. Although, there is enough potential for integration of rainwater harvesting, drip irrigation and plastic mulch to increase productivity of produce, no concerted effort has so far been made in this direction.

Therefore, an effort was made to integrate the rainwater harvesting with drip irrigation to increase productivity of lemon at Assam Agricultural University, Jorhat, Assam.

METHODOLOGY

The experiment on integration of rainwater harvesting and drip irrigation to increase productivity of lemon was conducted at the experimental farm, Department of Horticulture, Assam Agricultural University , Jorhat (26º47´N latitude, 94º12´E and 86.8 M). One water harvesting pond was designed for harvesting water for drip irrigation to cover 1 ha lemon plantation. The dimension of the pond as designed were top width 26m, top length 76 M , bottom width 14 M , bottom length 64 M and side slope 2:1 . The construction of pond was completed in March 2009. A dead storage of 1 meter depth of water for fish rearing as additional income generation was provided. The pond was lined with 250 micron thick lining film (Agri-film) for possible reduction in seepage losses with adequate soil cover. 2 years old plantations of lemon grown at 3 m x 3m spacing were selected for the drip irrigation studies. The objective of using drip irrigation was to apply the harvested water judiciously and 3 levels of drip irrigation was tested .The soil of the experimental site consisted of old alluvial soil with sandy loam structure (Table A).

The meteorological records of Jorhat pertaining to the water harvesting and irrigation were collected from meteorological observatory at Assam Agricultural University, Jorhat and presented as Fig. A.

To achieve the objective of the study an experiment based on 4x2 factorial arranged in a Randomized Block Design with three replications was laid out. Four levels of irrigation regime *viz.,* 1.0, 0.8, 0.6 fractions of PE and rain fed and two levels of mulch *viz.,* black plastic mulch of 50 micron thickness and no

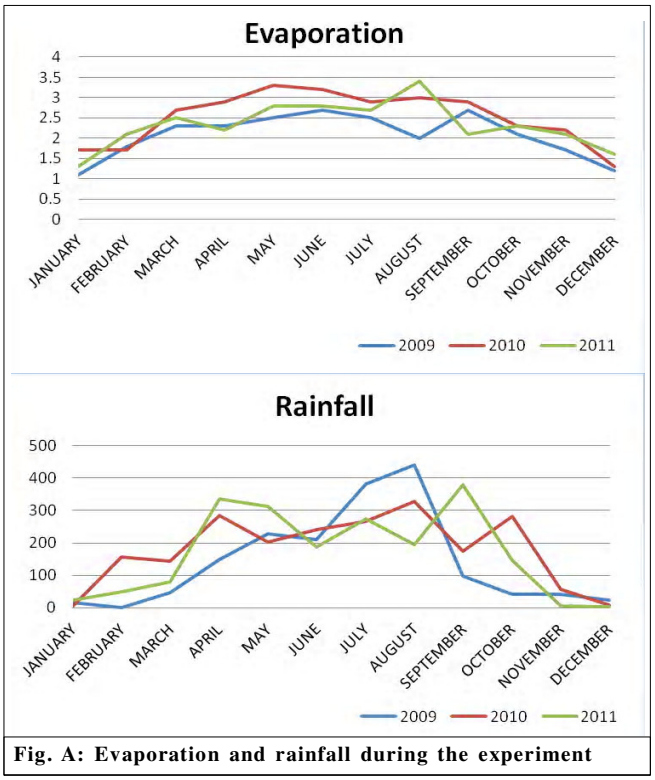

Fig. A: Evaporation and rainfall during the experiment

mulch were tested on two years old lemon plants. To deliver the required quantity of water 2 numbers of 2 LPH (liters per hour) drippers were fitted on 1.2 cm diameter lateral which were aligned with the base of the plant. Each lateral was provided with a lateral valve to regulate the flow. To evaluate the relative effectiveness of each treatment, data on yield attributes (plant height, stem girth and canopy diameter), total water applied and yield was recorded. To work out the economics of the water harvesting and drip irrigation integration, observations on yield and quality of water harvested, water used for irrigation, yield and yield attributing parameters of the crop were recorded.

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

Water yield :

The water harvested in the pond was measured using staff gauge installed in the ponds. It was observed that maximum rain water (4947587 liters) was harvested during the month of August. The average temporal variations in water

Table A: Soil of the experimental plot

Soil structure			pH	Nutrient status			
Sand (%)	Silt (%)	Clay (%)		Organic carbon (%)	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)
69.6	9.4	21	4.6	0.69	149.96 to 150.72	38.29 to 38.94	65.23 to 65.61

yield over three years period has been presented in Table 1. Water available for irrigation has also been shown considering a dead storage of 1 meter depth of water. It can be seen from the table that the harvested water even during the driest month (*i.e.* March) was sufficient to irrigate 1 ha lemon plants through drip irrigation.

Quality of harvested water :

The quality of harvested water of the pond was analysed and the result was compared with ground water from a tube well in the same farm. The results have been presented in Table 2. It can be seen from the table that high concentration of iron in ground water make harvested water a better choice for drip irrigation.

Water application through drip :

Analysis of year wise as well as pooled data for three years (Table 3) revealed that black plastic mulch did not significantly influence the plant height and stem girth of lemon. Only moisture regimes resulting from different levels of drip irrigation influenced the plant height and stem girth and drip irrigated plants exhibited significantly higher values of both the parameters when compared with rainfed plants. However, stem girth and plant height resulting from different drip irrigation levels *viz.,* 1.0 PE, 0.8 PE and 0.6 PE were statistically at par.

Table 1 : Measurement of pond water

Month	Volume of water in pond	Water available for irrigation (litres)
April	4301960	2325960
May	3838096	1862096
June	4037980	2061980
July	4236672	2260672
August	4947587	2971587
September	3820112	1844112
October	3378842	1402842
November	2670843	694843
December	2448923	472923
January	2659683	683683
February	2670780	694780
March	2804968	828968

Table 2 : water quality comparison (harvested water vs ground water)

Components	Quality of ground water	Quality of pond water
Acidity mmol/l	0.5	0.3
Alkalinity mmol/l	2.8	0.4
Phosphate mg/l po_4^{3-}	3.0	0
Ammonium mg/l NH_4^+	4.9	0.2
pH	7	4.4
Nitrate	0	0
Nitrite	0	0
Carbonate hardness mmol/l or 2°d	4	0.8
Total hardness mmol/l or 2°d	2.5	0.6
Oxygen mg/l	2.2	6.1
Iron mg/l	1.1	0.6
Chloride mg/l	0.4	8
Magnesium mg/l Mg^{2+}	100	100
Calcium mg/l Ca^{2+}	10	5
Manganese mmol/m^3	5.5	1.9
Conductivity µs/cm	250	49.5

Interaction effect of moisture regime and mulching on both the parameters were non significant throughout the experiment period. Both mulching and moisture regimes significantly influenced the canopy diameter of lemon plants as revealed by analysis of pooled data. However, analysis of year wise data showed that black plastic mulch had no significant effect on plant canopy diameter. Overall moisture regime resulting from drip irrigation at 1.0 PE level showed highest canopy diameter followed by 0.8 PE and 0.6 PE which were statistically at par but at the same time significantly better than the rainfed plants. Pooled data also indicated that plants mulched with black plastic had significantly better canopy diameter compared to un-mulched plants. However, interaction effect of moisture regime and mulching on canopy diameter , though significant during first two years, was non significant when three years data were pooled.

During all the three years of experimentation the treatments differed significantly with respect to yield in terms of number of fruits per plant. Year wise analysis of data revealed that only moisture regime influenced yield of lemon and different levels of irrigation (1.0 PE, 0.8 PE and 0.6 PE) were statistically at par while altogether they were significantly better than rain fed plants. However, analysis of pooled data revealed that both mulching and moisture regime significantly influenced yield, but, their interaction remained non-significant. Plants mulched with black plastic film yielded 104.33 fruits/plant which was significantly better compared to 97.75 fruits per plant of un-mulched plant (Table 3). The yield of different drip irrigation levels of 1.0 PE, 0.8 PE and 0.6 PE (122.17, 119.44 and 113.05 fruits/plant) were at par and were significantly better as compared to rain fed plants (49.50 fruits/plant). The reason for better growth and yield in drip irrigated treatments may be that lemon plants being evergreen, they require good amount of moisture throughout the life period especially during flowering and bearing stage. The drip irrigation system was able to supply the optimum amount of moisture during the dry period of the year.

Cost economics of integration of rain water harvesting and drip irrigation has been presented in Table 4. The cost economics has been worked out assuming a life span of drip irrigation as 15 years (NABARD, 2011). The BCR (Benefit Cost Ratio) has been worked out on the basis of net present worth of cost and benefit for 15 years. Since the experiment was carried out for 3 years the cost and benefit values for rest of

Table 3 : Yield and yield attribute as influenced by moisture regime and mulches in lemon

Parameters (year wise and pooled)	Moisture regime					Mulching			Interaction (C.D.=0.5) 1=Ax B 2=Ax Year 3=Bx Year 4=AxBxYear
	Drip								
	1.0PE	0.8PE	0.6PE	Rain fed	C.D.=0.5	Non mulch (NM)	Plastic mulch (PM)	C.D.=0.5	
Plant height (m)									
2009	1.66	1.58	1.62	1.10	0.08	1.49	1.49	NS	NS
2010	2.01	1.87	1.98	1.39	0.10	1.80	1.84	NS	NS
2011	2.15	1.96	2.08	1.39	0.08	1.89	1.91	NS	NS
Pooled	2.04	1.85	1.98	1.35	0.59	1.80	1.82	NS	NS
Canopy diameter (m)									
2009	2.59	2.47	2.47	1.86	0.14	2.36	2.35	NS	1
2010	2.85	2.76	2.70	2.22	0.11	2.60	2.67	NS	1
2011	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)									
2009	5.57	5.52	5.77	2.92	0.48	4.98	4.93	NS	NS
2010	16.31	17.77	17.52	11.10	2.17	15.49	15.86	NS	NS
2011	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
Yield (no. of fruit/plant)									
2009	109.50	102.50	104	37	9.53	83.50	93	NS	NS
2010	107	108	92	37.50	15.02	84.5	88	NS	NS
2011	150	147.33	143.17	74	54.13	125.25	132	NS	NS
Pooled	122.17	119.44	113.05	49.5	17.66	97.75	104.33	4.81	NS

Table 4 : Cost economics of integration of rain water harvesting and drip Irrigation in lemon (sample for treatment drip (0.8PE)+ No mulch)

Particulars / years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Drip irrigation	30000														
Plantation creation	4000	1800	2000	2000	5000					1800	2000	2000	5000		
Maintenance cost						7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
water harvesting pond @ Rs 15 per cubic meter	74100														
Cost of raising fish*	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Total cost	111100	4800	5000	5000	8000	10500	10500	10500	10500	12300	12500	12500	15500	10500	10500
Income (fish)		20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Income (lemon)				70016	70016	70016	70016	70016	70016	70016	70016	70016	70016	70016	70016
Total income	0	20000	20000	90016	90016	90016	90016	90016	90016	90016	90016	90016	90016	90016	90016
Cash flow	-111100	15200	15000	85016	82016	79516	79516	79516	79516	77716	77516	77516	74516	79516	79516

*additional income as per NABARD cost norms , NPW of cost @15% rate of interest Rs.159, 416.00, NPW of benefits @15% rate of interest Rs 353,152. 00 BCR 2.21

Treatment wise BCR

Treatments	Drip(1.0 PE) + no mulch	Drip(0.8PE) + no mulch	Drip(0.6PE) + no mulch	Drip(1.0PE) + plastic mulch	Drip(0.8PE) + Plastic mulch	Drip(0.6PE) + Plastic mulch	Rain fed + no mulch	Rain fed + Plastic mulch
Average yield (no. of fruits '000/Ha)	122.08	127.77	127.41	145.67	140.24	121.11	50.48	64.56
Average water applied (mm/year)	64.21	51.37	38.49	64.21	51.37	38.49	-	-
Income from lemon (Rs)	65464	70016	69728	74336	69992	54688	15384	16648
BCR	2.10	2.22	2.21	2.33	1.82	1.48	0.81	0.64

the years were estimated from the experimental results. The returns from fish rearing are hypothetical based on NABARD estimate (NABARD 2011). The net income of Rs 74336.00, Rs 70016.00, Rs 69992.00 and 69728.00 per hectare were obtained from treatments drip (1.0 PE)+ plastic mulch , drip (0.8 PE)+ no mulch, drip (0.8 PE) + plastic mulch and drip (0.6 PE)+ no mulch, respectively. The best benefit to cost ratio, therefore, could be expected from drip (1.0 PE)+ plastic mulch followed by drip(0.8 PE)+ no mulch. It reveals that though plastic mulch is a costly intervention the end results justify the cost. From the present experiment it appears that integration rainwater harvesting and drip irrigation is a viable option for a sustainable and integrated production system.

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