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Enhancing Productivity of Citrus through Rainwater Conservation and Micro-irrigation in Central India

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Abstract: *Scarcity of irrigation water is one of the major causes of low productivity and decline of citrus orchards in central India. Rainwater harvesting, recharging it to groundwater and it's efficient utilization in citrus orchards is need of the hour for sustainable citriculture in water scarce region. Keeping this in view, the study was conducted to explore the feasibility of rainwater harvesting and it's use through drip irrigation in citrus. Various* in-situ *rainwater conservation treatments viz., continuous trenching, continuous bunding, staggered trenching between the rows across the slope (4.2%) and control (without any soil and water conservation treatment) were evaluated in Nagpur mandarin orchards at Nagpur during 2003-2009. The continuous trenching produced the best response conserving 38% runoff and 32.28% soil besides 15.7% higher fruit yield with better fruit quality. Moreover, rainfall runoff from 3.2 hectare of land with continuous trenches was harvested in a tank of size 35m×35m×3m and recycled at the best level of irrigation (60% of pan evaporation) through drip with black plastic mulch of 100 micron thickness in 1ha of Nagpur mandarin. The harvested water also recharged the groundwater in the nearby wells and water from wells was used for irrigation purpose after drying of water in harvesting tanks during May and June. Over all, the fruit yield was enhanced up to 110% with better quality fruits under rainwater conservation practices and groundwater use over rain-fed trees. The study suggested for the combine adoption of rainwater harvesting strategies and drip irrigation for sustainable production of citrus orchards in central India.*

Key words: *Citrus, Water harvesting, Micro-irrigation, Yield*

INTRODUCTION

Citrus is the third important fruit crop after banana and mango in India. Nagpur mandarin (Citrus reticulata Blanco), one of the premier citrus cultivar, is grown in around 4.85 lakh hectares of central India (Singh and Srivastava, 2004). The crop is mostly grown on Vertisol of gently sloppy lands, which is characterized with producing abundant runoff during monsoon on one hand and soil moisture shortage for sustaining the crop in post monsoon period on the other (Huchche et al., 1999; Panigrahi *et al.*, 2010). Although, some in-situ runoff conservation measures for different crops such as lime (Panigrahi *et al.*, 2005) and sweet orange (Arora and Mohan, 1985) were advocated for better growth and production, the information such as this is lacking for Nagpur mandarin. Moreover, rainwater harvesting in tank and recycling it in orchards is one of the potential options for enhancing productivity of citrus in water scarce region.

The citrus in central India is basically irrigated by bore well or dug well through basin or furrow irrigation method. For last few years, the water level in wells is declined alarmingly creating water shortage in summer for sustaining the crop. So every year thousand hectares of the orchard is permanently wilted due to short of water, which is a great economical loss for the orchard growers of this region. Hence, proper irrigation water management by optimum use of available water

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resource along with water resource development in the region is quite necessary (Panigrahi *et al.*, 2013). Water management studies in Nagpur mandarin show that optimum soil water regime under drip irrigation could increase its growth and yield to a better extent (Panigrahi *et al.*, 2011). Also mulching by plastic polythene has proved its effectiveness in conserving the soil moisture and increasing the growth, yield and quality of different citrus cultivars (Mohanty *et al.*, 2002; Panigrahi *et al.*, 2012). However, the information on rainwater harvesting and recycling it through drip irrigation and mulching for citrus is meager. Keeping this in view, a study was undertaken to evaluate the performance of rainwater harvesting and recycling the harvested water through drip irrigation and plastic mulch in Nagpur mandarin. The impact of rainwater harvesting on groundwater of the study site was also studied.

MATERIALS AND METHODS

The experiment was carried out at research farm of National Research Centre for Citrus, Nagpur, India during 2003-09 on one-year-old Nagpur mandarin plants budded on rough lemon root stock with 6 ? 6 meter plant spacing. The treatments imposed were T_1: continuous bunding, T_2: continuous trenching, T_3: staggered trenching between rows and control (C): without any soil and water conservation measure, in randomized block design with seven replications in blocks of size 36?18 m^2 on slope of 4.2%. The soil type was clay loam with field capacity and permanent wilting point of 24.8% (weight basis) and 15.7% (weight basis) respectively. Runoff was measured through multi-slot divisor and well-stirred runoff samples were collected for estimation of sediment yield and nutrients loss after each rainfall under different treatments. Runoff sample analysis consisted of alkaline $KMNO_4$ distillation for available N, $NaHCO_3$ (pH 8.3) extractable-P as Olsen-P, 1N neutral NH_4OAc – K (Tandon 1998). The moisture content at 0-30 cm depth was recorded each week by neutron moisture probe (Troxler model-4300) in various treatments.

A water harvesting tank of size 35m×35m×3m was constructed in 2005. Prior to construction of the tank, the groundwater level in the wells present in the orchards were taken. The plants were irrigated by groundwater in initial years (2003–2005). The irrigation systems studied in the orchards were traditional surface irrigation and drip irrigation with and without mulch and compared with rain-fed treatment. After construction of the tank, the harvested water was used at the best level of drip irrigation (60% of pan evaporation) with black plastic mulch (100 micron thickness). Mulching was done by one piece of 1.0 m 1.0m size polythene sheets on each tree basin keeping the tree at the centre in 1ha of Nagpur mandarin. The harvested water also recharged the groundwater and water from wells was used for irrigation purpose after drying of tank during May and June. The volume of water required was computed using the equation, V = Ep, Kc, Kp, Wp, D, where V, Volume of water (litre/plant/day); Ep, cumulative pan evaporation for two consecutive days (mm); Kc, crop factor; Kp, pan factor ; Wp, wetting factor; D, canopy diameter observed at noon. The crop factor was taken as 0.6 and pan factor as 0.7 in winter and 0.8 in summer as per FAO-24 (Doorenbos and Pruit 1997). Recommended dose of fertilizers was applied. The vegetative growth parameters such as plant height, stem height, canopy diameter, stock and scion girth were measured and their incremental magnitudes under different treatments were compared.

The fruits were harvested from each plant and their weight was measured to estimate the yield in different treatments. Five fruits per tree were taken randomly for determination of fruit quality (juice percent, acidity and total soluble solids) parameters. Juice was extracted manually by juice extractor and it's percent was estimated on weight basis with respect to fruit weight. The total soluble solid (TSS) was determined by digital refractometer and acidity was measured by volumetric titration with standardized sodium hydroxide, using phenolphthalein as an internal indicator. The economics of citrus cultivation under different treatments was determined by the indices such as net return and benefit-cost ratio (B/C).

The data generated were subjected to analysis of variance (ANOVA), and significance of the data within the treatments was determined using SAS-9.2 statistical software.

RESULTS AND DISCUSSION

Runoff, Soil and Nutrient Conservation

The mean annual rainfall, runoff and soil loss observed under different treatments indicated that the maximum runoff (38.15%) and soil loss (4.98 t/ha) occurred in control, whereas the minimum (runoff 27.3%; soil loss 3.74 t/ha) was under continuous trenching, followed by continuous bunding (Table1). The runoff and soil loss, occurred under staggered trenching, were 10 and 6% lower over control. Continuous trenching conserved the maximum runoff (28.4%) and soil (24.9%) among the conservation measures over control due to higher runoff conservation in trenches between the rows.

The analysis of runoff samples under different treatments for available N, P and K (Table 1) showed that all the nutrients loss was maximum in control (1.08 kg N/ha, 0.24 kg P/ha and 2.08 kg K/ha), and lowest in continuous trenching (0.62 kg N/ha, 0.13 kg P/ha and 1.09 kg K/ha) followed by continuous bunding. The lowest nutrients loss under continuous trenching was attributed to the lowest soil loss. Due to heavy loss of upper fertile soil through runoff, the nutrient concentration in eroded soil was invariably higher than the original soil.

Table 1
Runoff, Soil and Nutrients Loss under Different Soil and Water Conservation Measures in Nagpur Mandarin

Treatment	*Run off (mm)*	*Soil loss (t/ha/yr)*	*Nutrients loss (kg/ha)*		
			N	*P*	*K*
Continuous bunding	263 (28.8)***	4.11	0.75	0.15	1.24
Continuous trenching	249 (27.3)	3.74	0.62	0.13	1.09
Staggered trenching	313 (34.3)	4.67	0.87	0.17	1.57
Without conservation measure (Control)	348 (38.15)	4.98	1.08	0.24	2.08

**ARF, Annual Rainfall, ***Figures in parenthesis indicate runoff as % of mean annual rainfall.

Soil moisture variability and groundwater recharge

The mean monthly moisture content at 0-30 cm soil profile revealed that the soil moisture status improved considerably in various conservation treatments over control (Table 2). Among different treatments, the highest soil moisture content (24.55-30.52%, v/v) was observed under continuous trenching followed by continuous bunding (24.25-28.33%, v/v). The moisture content under staggered trenching was 23.43-26.92% (v/v) in various months. The higher moisture content in continuous trenching was due to maximum rainwater conservation during the rainy period. The moisture content under various conservation measures and control reduced with time, except during the month of February, due to some unseasonal rainfall (11 mm) in the month. This was due to more consumptive use of water by the plants under increased soil moisture content under various conservation treatments. Moreover, the moisture content under different treatments did not vary significantly at the initial period (October) of observation. But during the period between November and February, the moisture content under various conservation measures was significantly higher over control.

The groundwater level in the wells present in the orchards was increased by 1.5-2.3 m after construction of water harvesting tanks compared to water level before construction.

Table 2
Soil moisture content (%, v / v) at 0.30 m depth under different soil and water conservation measures in Nagpur mandarin*

Treatment	*Month*								
	Oct.	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*
Continuous bunding	28.33	28.26	27.94	26.76	28.24	27.45	26.45	26.15	24.25
Continuous trenching	30.52	30.31	28.86	28.45	30.37	27.75	26.57	26.35	24.55
Staggered trenching	24.36	24.18	23.85	23.74	25.69	26.92	25.88	24.20	23.43
No conservation measure Control)	23.63	23.38	21.84	21.54	23.46	25.88	23.85	22.80	22.33
**CD (P=0.05)	NS	1.92	2.21	2.40	2.97	NS	NS	NS	NS

**CD, Critical difference at 5% probability, NS, Not significant.

Vegetative growth, yield, fruit quality and economics

The incremental growth of vegetative parameters viz., plant height, canopy volume, and stem girth (Table 3) showed that all the parameters were significantly higher under various conservation measures over control. The highest magnitude of the incremental plant growth parameters was observed in continuous trenching. Similarly, all the conservation measures produced higher fruit yield (7-29%) with better fruit quality over control. The highest fruit yield (9.60 kg/plant) was observed in continuous trenching. Quality assessment of fruits showed that the juice contents (40.42%) and TSS (10.10 ^{0}Brix) were significantly higher under continuous trenching treatment. The higher vegetative growth and fruit yield with better fruit quality in various conservation measures was due to better availability of soil moisture to mandarin plants during flowering and fruiting stages during the post-monsoon period.

Table 3
Incremental vegetative growth, fruit yield and quality of Nagpur mandarin under various soil and water conservation measures

Treatment	*Vegetative growth**			*Fruit yield***			*Fruit quality***		
	Plant height (m)	*Stem girth (cm)*	*Canopy volume (m^3)*	*No. of fruits/ plant*	*Fruit weight (g)*	*Total yield (kg/plant)*	*Juice (%)*	*Acidity (%)*	*TSS (^{0}Brix)*
Continuous bunding	0.28	2.23	0.759	65	136.7	8.88	39.33	0.83	10.00
Continuous trenching	0.35	2.4	0.846	69	139.2	9.60	40.42	0.82	10.10
Staggered trenching	0.24	1.8	0.563	59	135.4	7.98	37.66	0.84	9.98
Without conservation measure (Control)	0.19	1.35	0.402	55	135.2	7.43	35.42	0.86	9.94
# CD (P = 0.05)	0.08	0.3	0.031	2.5	NS	0.31	3.6	NS	0.05

CD: Critical difference at 5% probability.

The economics of citrus production (Table 4) under continuous trenching, water harvesting tank, drip irrigation and mulch was found superior (net return Rs. 1.8 and B/C, 2.0) compared to that under rain-fed condition (net return: Rs. 1.1 lakh, B/C, 1.7)

CONCLUSION

Continuous trenching was found to be a superior soil and water conservation technique for cultivation of Nagpur mandarin. The method warrants it's adoption in mandarin orchards of Central India and elsewhere having similar agro-

Table 4
Economics of citrus cultivation under rainwater harvesting and drip irrigation

Treatments	*Yield (t ha^{-1})*	*Gross return (Rs. in lakhs)*	*Net return (Rs. in lakhs)*	*B/C*
#RWHT + CT + DI + Mulch	13.0	2.4	1.8	2.0
Rain-fed system	8.5	1.5	1.1	1.7

#RWHT: rainwater harvesting tank, CT: continuous trenching; DI: drip irrigation

pedological conditions. Moreover, the citrus cultivation under continuous trench, drip irrigation and plastic mulch using water from rainwater harvesting tank was found more productive and economical compared to rain-fed citriculture in central India. The technique therefore suggested to be adopted in the study region for improving the quality production of citrus without bringing any sizeable reduction in soil fertility.

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