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Impact of varying soil moisture regimes on growth and soil nutrient availability in mango

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ABSTRACT

A field experiment was conducted at the Research Farm of Central Institute for Sub-tropical Horticulture, Lucknow during 1995-1999 to evaluate the effect of different soil moisture regimes on tree growth and soil nutrient dynamics in mango orchard. It was observed that the regulated irrigation under available soil moisture (ASM) depletion levels influenced tree growth and nutrient availability. The annual increase in stem girth, tree height and canopy spread of trees under 45% ASM level was found to be superior to control. Available N, P, K and DTPA-extractable micronutrients Zn, Cu, Mn and Fe registered the maximum values in 45% ASM levels followed by 60% and 30% ASM depletion levels. Soil nutrients were positively and significantly correlated to one another. Available nutrients were in higher range in upper 50 cm layer as compared to deeper layers.

1. INTRODUCTION

Understanding the impact of soil moisture regimes on agroecology of fruit trees is an important for identifying the yield-limiting factors and forms a basis for future water management strategy (Purushottam *et al.*, 2008; Dadhwal *et al.*, 2012; Madile *et al.*, 2012). This has gained importance under the threat of perceived climate change wherein the pattern, distribution, frequency and amount of rainfall are likely to change making it challenging for optimum resource conservation (Sharda *et al.*, 2010). Water stress is ubiquitous limiting factor in intensively cultivated cropping systems including fruit tree based agroecosystem (Biswas *et al.*, 2012). Irrigation of fruit trees not only provides some security in protecting a large investment with potentially high returns against droughts, but also serves to increase and stabilize production (Bhriguvanshi *et al.*, 2012; Joshi *et al.*, 2012). Henceforth, emphasis on proper irrigation water management has been receiving considerable attention in both irrigated and rainfed agri-horticultural systems to maintain optimum soil moisture regime and sustain productivity (Adak *et al.*, 2012). Under limited water resources, deficit irrigation based on soil moisture storage can be more profitable for a farmer to maximize crop

water productivity instead of maximizing the harvest per unit land (English *et al.*, 2002; Melgar *et al.*, 2008; Pe' rez-Pe' rez *et al.*, 2008; Greets and Raes, 2009; Panigrahi *et al.*, 2010).

Mango is an important economic crop of India both for its domestic and export markets. India is the largest producer of mango accounting for nearly 50% of the total world production, 39% of the area under fruit crops in India and 21% of the total fruit production of the country. The economy of mango growing belt of Malihabad region of Uttar Pradesh is greatly affected and often determined by the mango production. However, apart from several biotic stresses, abiotic factors like inadequate water and nutrient management contributes to its low productivity. There are some water availability restrictions in the region due to rapid decrease in ground water table and for this reason, water resources must be judiciously used in irrigation water management.

Information on nutrient dynamics under differential soil moisture level is essentially required for optimum water and nutrient management for sustainable fruit production (Misra and Tyler, 2000; Rajput and Patel, 2006; Vijayakumar *et al.*, 2011). Orchard ground floor management system has its impact on soil nutrient

dynamics and tree growth and yield (Rahman *et al.*, 2011; Rodrigues *et al.*, 2011). Since soil moisture is an important parameter as it significantly controls the nutrient availability, its distribution and mobility within the soil, water has to be applied to root zone to save the leaching losses of nutrients and as per the prevailing soil moisture level. Water requirement is highest for both bearing as well as non-bearing mango orchards during summer months. If water deficit is experienced during active growth phases, it arrests tree growth and causes loss to production and quality. Therefore, irrigation scheduling should be based on available soil moisture depletion level in consonance with climatic variations. Since the information on tree growth, variability of nutrients and its interaction under differential soil moisture depletion levels is lacking, the present study was undertaken in a Dashehari mango orchard of subtropical region.

2. MATERIALS AND METHODS

A field experiment on irrigation, based on available soil moisture (ASM) depletion level was conducted on a two year old mango cv Dashehari plantation at a distance of 10×10 m in research farm of Central Institute for Sub-tropical Horticulture (CISH), Lucknow during 1995-1999. The experiment was laid out in a randomized block design (RBD) with five replications. Irrigation scheduling was done at 30 (T_2), 45 (T_3) and 60 (T_4) per cent ASM levels along with a control (T_1) in which water was applied as flooding as per farmer's practice. Measured quantity of water was applied to the plants in the basin to maintain desired ASM levels in the treatments. Recommended fertilizer doses were applied within the tree basin each year. Plant height, girth of stem and canopy spread (North-South and East-West) were measured twice (August and March) every year to evaluate the effect of different irrigation scheduling on tree growth. Composite soil samples corresponding to horizontal 30 cm (x_1) and 60 cm (x_2) and vertical 0-25 cm (z_1), 25-50 cm (z_2) and 50-100 cm (z_3) distances were collected from each tree under each treatment at the end of each irrigation. The soil of the experimental site was mixed hyperthermic family of Typic Ustochrepts, silt loam in texture having pH 8.3, EC 0.23 dSm⁻¹, bulk density (BD) 1.35 Mg m⁻³, water holding capacity (WHC) 36.5%, infiltration rate 0.8 cm hr⁻¹, organic carbon 0.37 per cent with available P (4.5 ppm) and K (110 ppm). Available micronutrients (Zn, Cu, Mn and Fe) were determined by using Diethylene triamine penta acetic acid (DTPA) extraction method (Lindsay and Norvell, 1978). Available N, P and K were estimated following standard procedures. The effect of different treatments on tree growth and soil parameters were tested both for the individual years and also pooled over years as per standard procedure of analysis of variance (ANOVA). ANOVA, Coefficient of variations (CV), standard deviations and correlation coefficients were computed using statistical software SAS 9.3.

3. RESULTS AND DISCUSSION

Effect of Different Soil Moisture Regimes on Tree Growth and Canopy Spread

Tree growth parameters like plant height, stem girth, canopy spread in north-south and east-west directions were influenced by the available soil moisture (ASM) depletion levels (Table 1). Maximum plant height was recorded at irrigation given to 45% ASM depletion level (T_3). Over the years, T_3 recorded 54, 55, 60, 53% increment in height over the control (T_1), 27, 5, 9, 16% increment over 30% ASM depletion level (T_2) and 18, 24, 20, 26% increment over 60% ASM levels (T_4) during 1995-99, respectively. However, pooled data indicated that maximum plant height was 2.35 m in T_3 which was 55, 13, and 22% higher than T_1 , T_2 and T_4 treatments, respectively. The growth rate (cm yr⁻¹) in the tree height was in a range of 16.5 in control (T_1) to 24.7 in T_2 treatment (Table 1). The stem girth of mango tree ranged from 39.5 to 23.5 cm in 1998-99 compared to 10.1 to 18.3 cm in 1995-96. From the data, it was observed that the irrigation at 45% ASM depletion level recorded maximum stem girth over the other treatments. This was true both for individual years as well as pooled data. The maximum mean stem girth of 30 cm was recorded in T_3 which was 72, 16 and 28% higher as compared to T_1 , T_2 and T_4 treatments, respectively. In case of canopy spread in N-S direction, it was observed from the pooled data that the maximum canopy spread of 259.8 cm was recorded in T_3 as compared to 149.4, 202.2 and 209.3 cm in T_1 , T_2 , and T_4 treatments, respectively. Similarly, a range of 110.3 to 254.6 cm canopy spread was observed in E-W direction. The increment ranged from 93.7 to 140 cm in T_1 , 120 to 280 cm in T_2 , 170.5 to 350 cm in T_3 and 150.3 to 230 cm in T_4 .

Soil moisture plays an important role in tree growth and fruit developmental stages (Al-Yahyai *et al.*, 2005) as it is required to maintain the optimum moisture regime within the rhizosphere. Under experimentation with drip irrigation, Sujatha *et al.* (2006) reported that although the mango tree did not differ in its height and girth within a season but differs over years of experiment. Reddy *et al.* (2009) observed that canopy spread significantly varied over a period of five years of experimentation under drip irrigated regimes along with all nutrition treatments over control. Water management strategy like regulated moisture deficit reported to have significant impact on tree height, stock growth girth, scion girth and canopy volume in Nagpur mandarin (Panigrahi and Srivastava, 2011).

Availability of N, P and K as Influenced by Soil Moisture Regimes

Nitrogen (N) is generally the most important macronutrient in crop fertilization, and inadequate N supply often restricts tree growth and final yield of fruit crops (Rufat and DeJong, 2001; Rufat *et al.*, 2011). Availability of N is influenced by several abiotic factors, out of which soil moisture regime plays dominant role in solubility and

Table: 1**Plant height, stem girth, canopy spread as influenced by ASM depletion levels**

Treatment	Plant height (cm)				pooled mean
	1995-96	1996-97	1997-98	1998-1999	
Control	124	142	150	190	151.5
ASM 30% depletion level	151	210	220	250	207.8
ASM 45% depletion level	191.5	220	240	290	235.4
ASM 60% depletion level	162.7	178	200	230	192.0
C. D. (p = 0.05)					69.9
Treatment	Stem girth (cm)				pooled mean
	1995-96	1996-97	1997-98	1998-1999	
Control	10.1	17.0	19.0	23.5	17.4
ASM 30% depletion level	12.3	21.3	30.5	39.0	25.8
ASM 45% depletion level	18.3	30.0	32.0	39.5	30.0
ASM 60% depletion level	14.4	26.0	23.7	30.0	23.5
C. D. (p = 0.05)					5.50
Treatment	Canopy spread (North- South) (cm)				pooled mean
	1995-96	1996-97	1997-98	1998-1999	
Control	87.5	168	152	190	149.4
ASM 30% depletion level	108.7	202	178	320	202.2
ASM 45% depletion level	184	255	260	340	259.8
ASM 60% depletion level	124.3	213	250	250	209.3
C. D. (p = 0.05)					20.25
Treatment	Canopy spread (East- West) (cm)				pooled mean
	1995-96	1996-97	1997-98	1998-1999	
Control	93.7	125	82.5	140	110.3
ASM 30% depletion level	120	170	167	280	184.3
ASM 45% depletion level	170.5	243	255	350	254.6
ASM 60% depletion level	150.3	230	220	230	207.6
C. D. (p = 0.05)					19.95

mobility of the major nutrients. Results indicated that the available N content was significantly higher in T_3 as compared to other soil moisture levels (Table 2). The N availability up to 60 cm (x_1) horizontal distance was in the range of 0.022 to 0.032%. N content in the top 50 cm soil depth was significantly higher in all the treatments as compared to lower depths; indicated that availability of N was controlled by the factors within effective root zone. This may be due to the fact that microbial activation and decomposition of organic matter, release of nutrients and their mobility are impacted by soil depth and soil moisture regimes.

A significant interaction of soil available P under different soil moisture regimes was observed (Table 2). Higher available P was found to be varying in the range of 10.73 to 14.67 ppm in T_3 and T_4 treatments as against 5.62 ppm in T_1 . Even increasing distance from tree trunk basin (x_2), it was inferred that the range was somewhat lower in magnitude, *i.e.* 10.75 to 12.97 ppm. The interaction of available P and ASM levels was significant among the treatments, distances and upper layers having more available P as compared to deeper soil depth. Several field studies have reported evidence of significant interaction between soil available P and soil moisture regimes impacting on crop growth and yield parameters (Fredeen *et al.*, 1989; Kaspar *et al.*, 1989; Gutierrez-Boem and Thomas, 1998, 1999). The increase in P diffusion with increasing soil water content has been suggested as a possible reason of these results. As P diffusion takes place only within a few

millimeters around the root, root growth is an important factor in determining the volume of the depletion zone and the amount of P absorbed (Barber, 1995). Therefore, effects of P and water availability on root growth could affect P absorption, which, in turn, may influence shoot growth, physiological and yield and quality parameters.

Mean available K was recorded in the range of 63.33 to 65.72 ppm in different soil moisture depletion regimes while a mean of 58.58 ppm was observed in control (Table 2). A higher value of K (69.70 to 76.76 ppm) in x_2 distance was found. Top layer soil stored higher available K as compared to the bulk soil in deeper layers. Potassium transport from the bulk soil to the root occurs mainly via diffusion in soil solution, a process driven by the K^+ concentration gradient between the root surface and the adjacent soil, which is formed when the rate of K^+ uptake exceeds that of K^+ supply by mass flow. K^+ concentration in the vicinity of the root surface is lowered in response to plant uptake. Soil moisture affects soil K availability and diffusive flux, as well as K^+ uptake via its effects on root growth and activity (Mengel and Von Braunschweig 1972; Zeng and Brown, 2000). Increasing soil moisture increased the diffusive K^+ flux in the soil and the efficiency of applied K. Low soil moisture restricted K^+ diffusion and K^+ uptake as a result of increased impedance at low soil moisture (Kuchenbuch *et al.*, 1986). Drying soil limited K^+ uptake by corn due to reduced root growth, resulting from increased impedance for K^+ diffusion at low soil moisture.

Table: 2
Availability of N, P and K as influenced by soil moisture regimes

Treatments	N (%)		P (ppm)		K (ppm)	
	X ₁	X ₂	X ₁	X ₂	X ₁	X ₂
Control						
Z ₁	0.024	0.027	7.60	9.95	68.50	71.67
Z ₂	0.022	0.024	5.60	5.65	62.63	69.38
Z ₃	0.018	0.017	3.65	3.90	44.60	50.22
Mean	0.021	0.022	5.62	6.50	58.58	63.76
ASM 30%						
Z ₁	0.035	0.036	15.20	8.60	81.45	91.52
Z ₂	0.047	0.032	12.00	10.20	65.83	73.73
Z ₃	0.023	0.022	5.00	5.50	49.87	65.00
Mean	0.035	0.030	10.73	8.10	65.72	76.75
ASM 45%						
Z ₁	0.035	0.036	24.00	22.75	81.38	89.03
Z ₂	0.029	0.028	11.50	10.00	65.00	74.17
Z ₃	0.022	0.025	8.50	6.15	50.70	67.07
Mean	0.028	0.030	14.67	12.97	65.69	76.76
ASM 60%						
Z ₁	0.031	0.028	11.55	15.25	77.75	83.60
Z ₂	0.024	0.024	10.95	11.30	60.02	66.77
Z ₃	0.019	0.044	4.15	10.75	63.33	69.70
C.D.(p= 0.05)	0.0002	0.006	3.02	3.4	2.06	3.6

Where, X₁ and X₂ stand for horizontal distance at 30 and 60 cm; and Z₁, Z₂ and Z₃ indicate vertical depth at 25, 50 and 100 cm, respectively.

Micronutrient Dynamics Under Differential Soil Moisture Regimes

The DTPA extractable Zn and Cu are presented in Table 3. The DTPA-Zn content of the soils under different soil moisture system varied from 0.76 to 1.01 ppm in x₁ and 1.07 to 1.14 ppm in x₂ distances, respectively. Considering critical limits of 0.5 ppm, the soils are sufficient in Zn. Upper layer soils indicated higher range of available Zn content (0.88 to 1.2 ppm) in x₁ and 1.2 to 1.33 ppm in x₂ distance, respectively. The mango orchard soils were found to be well supplied with DTPA-Cu with mean values ranging from 1.33 to 1.76 ppm in x₁ and 1.6 to 2.08 ppm in x₂ distance, respectively. The DTPA-Mn (Table 3) under different soil moisture depletion levels were found to vary from 17.53 to 24.45 ppm, indicating that the soils were well supplied with available Mn. Higher availability in the range of 16.35 to 21.32 ppm was found in T₂, T₃ and T₄ treatments as compared to 17.53 ppm in T₁. Lowest Fe content in x₁ and x₂ was recorded with mean values of 5.85 and 4.84 ppm, respectively. The mean Fe content was observed to be higher (6.25 to 7.16 ppm in x₁ and 6.14 to 7.2 ppm in x₂) in different soil moisture regimes (T₂, T₃ and T₄) rather than control. Considering critical limits of 2 ppm, the soils are sufficient in Fe. In general, the mango orchard ecosystem lies in the Indo-gangetic belt of Uttar Pradesh where Fe deficiency in soil is not a problem. It shows that the soils have inherent capacity to supply sufficient amount of

available Fe. However, variability due to water and nutrition management strategy may be prevailing. It has been observed from the interrelationships amongst the soil factors that the available N, P, K and micronutrients were positively and significantly correlated with each other. Available N, P and K were observed to be positively correlated among themselves. Cu, Mn and Fe were also positively but not significantly correlated to Zn. Mn and Fe positively correlated to Cu and among themselves. Micronutrient availability is an important aspect in fruit crops as it directly related to the growth and quality of fruit trees. Availability of micronutrients is influenced by their distribution in soils and other physico-chemical properties of the soil. Besides soil characteristics, soil moisture regimes play a pivotal role in governing the nutrient dynamics and fertility of soil (Bhargavanshi *et al.*, 2012).

4. CONCLUSIONS

The present study indicated that tree growth parameters like plant height, stem girth, canopy spread were influenced by the available soil moisture (ASM) depletion levels. Highest plant height, growth rate (cm yr⁻¹), stem girth, canopy spread in N-S and E-W directions were recorded in the treatment with irrigation scheduling based on 45% ASM depletion level. Available N, P, and K were highest in T₃ as compared to other soil moisture regime. Dynamics and availability of DTPA- extractable micronutrients were also

Table: 3
Micronutrient dynamics under differential soil moisture regimes (pooled mean for 1995-99)

Treatments	Zn (ppm)		Cu (ppm)		Mn (ppm)		Fe (ppm)	
	X ₁	X ₂	X ₁	X ₂	X ₁	X ₂	X ₁	X ₂
Control								
Z ₁	0.88	1.20	1.49	2.10	19.72	23.07	6.17	4.66
Z ₂	0.75	1.15	1.37	2.28	18.66	32.73	6.10	4.76
Z ₃	0.65	1.08	1.15	1.88	14.23	17.55	5.30	5.11
Mean	0.76	1.14	1.33	2.08	17.53	24.45	5.85	4.84
ASM 30%								
Z ₁	1.20	1.33	1.72	1.80	14.67	19.41	6.21	8.39
Z ₂	0.82	1.18	1.74	1.63	19.97	22.48	6.47	6.47
Z ₃	0.84	0.70	1.83	1.55	14.42	23.49	6.90	6.75
Mean	0.95	1.07	1.76	1.66	16.35	21.79	6.53	7.20
ASM 45%								
Z ₁	1.01	1.31	1.77	2.17	20.24	18.59	7.15	6.76
Z ₂	0.86	1.10	1.84	2.21	20.19	23.62	7.24	5.75
Z ₃	0.74	0.94	1.45	1.67	19.27	23.87	7.09	6.32
Mean	0.87	1.11	1.69	2.02	19.90	22.03	7.16	6.28
ASM 60%								
Z1	1.15	1.31	1.62	1.75	21.56	24.20	6.85	6.83
Z2	0.95	1.04	1.42	1.41	21.30	20.11	5.62	5.73
Z3	0.94	1.07	1.52	1.63	21.11	20.34	6.27	5.85
Mean	1.01	1.14	1.52	1.60	21.32	21.55	6.25	6.14

Where, X₁ and X₂ stand for horizontal distance at 30 and 60 cm; and Z₁, Z₂ and Z₃ indicate vertical depth at 25, 50 and 100 cm, respectively.

higher in the regulated water levels. Nutrients were positively and significantly correlated to each other.

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