Vol. 42, No. 3, pp 282-292, 2014
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Fertigation regime impacting productivity, moisture and nutrient distribution in mango under subtropical condition

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ARTICLE INFO

Article history :
Received : October, 2013
Revised : July, 2014
Accepted : September, 2014

ABSTRACT

A fertigation experiment was conducted to assess the spatio-temporal variation in soil water content, productivity, fruit quality and nutrient distribution in drip irrigated mango cv Dashehari under subtropical environment. Temporal variations in soil water content in the orchard was mainly governed by climatic factors particularly rainfall while the spatial variability was influenced by the hydrological properties of existing soil layer. Higher moisture content was recorded in the surface layer (0-15 cm) and it decreased down the depth. Higher moisture retention was observed in the treatment where fertigation was applied from September to second week of May which coincided with the crop phenological stages including fruit development. Lower moisture content (9-10%) was observed during flowering which is a pre-requisite for flowering in mango. The highest fruit yield (5.44 t ha^{-1}) was obtained in fertigation with N, P and K from the beginning of September to second week of May (T_5) as compared to 3.58 t ha^{-1} in basin application (T_1). Nutrient distribution in soil and leaf tissues showed better nutrient levels in all the treatments as compared to the control. Soil organic carbon (SOC) content ranged between 0.27-0.57%, available P between 11.7-18.93 mg kg^{-1} and K between 92.23-181.83 mg kg^{-1} across different treatments; however, the highest availability of these nutrients was recorded in T_5 treatment as compared to control (T_1). Available micronutrients (Fe, Mn, Cu and Zn) had showed improvement in T_5 over T_1 with highest values as Zn (0.75 mg kg^{-1}), Cu (3.63 mg kg^{-1}), Mn (8.53 mg kg^{-1}) and Fe (11.07 mg kg^{-1}). Leaf tissues were found in optimum range with the highest content as 0.25% P, 0.94% K, 29.67 mg kg^{-1} Zn, 35.33 mg kg^{-1} Cu, 68.33 mg kg^{-1} Mn and 262.33 mg kg^{-1} Fe. Correlation analysis showed yield is positively correlated with SOC content (r = 0.994**) and soil micronutrients (r = 0.898* to 0.994**). In contrast, TSS was non-significantly correlated with these parameters. Available soil K and P were positively and significantly correlated with yield and acidity as well as ascorbic acid content (r = 0.865* to 0.921**). Soil micronutrients were also significantly correlated with acidity and ascorbic acid content (r = 0.892* to 1.00**). Moreover, it was inferred that leaf micronutrients were positively correlated with yield yet mostly non-significantly correlated with quality parameters.

Key words :
Fertigation,
Mango,
Nutrient dynamics,
Quality,
Soil moisture content,
Yield

1. INTRODUCTION

Soil water dynamics reflects the integrated effects of climatic conditions, soil hydrological properties and vegetation at a site. Consequently, changes in hydrological regimes can have an important ecohydrological alteration. Notably, within season hydrological modifications have increased greatly because of ever changing climatic conditions, its extremes that results in changed hydrothermal regimes particularly with the shift in pattern of rainfall and ambient temperature (Ravishankar *et al.*, 2011). The changed hydrothermal conditions may have a significant influence on the content of soil water. Therefore, understanding the spatial and temporal variations in soil water content and its retention for longer period at least during fruit development is of immense importance for irrigation management in perennial fruit crops to avoid any moisture related stress (Fereres *et al*., 2003; Noar *et al*., 2006; Adak *et al*., 2011; Zhang *et al*., 2011; Kiggundu *et al*., 2012). Thus, the knowledge of the spatial variability of soil water content is of great importance for determining a soil sampling strategy, for understanding and modeling of water and nutrient movement, for designing field experiments and for many other investigations associated with the water management under different land use systems (Rajput and Patel, 2006; De Lannoy *et al*., 2006; Brocca *et al*., 2007; Chen *et al*., 2010; Zhu and Shao, 2008). Assessment of site-specific soil water measurement is important in orchard soils for improving the water use efficiency, fruit quality and water productivity (Bhriguvanshi *et al*., 2012a). Irrigation coupled with nutrient application at critical crop phenological stages are important for attaining optimum productivity and quality produce (Adak *et al*., 2012). Even, Bhriguvanshi *et al.* (2014) recorded the influence of different soil moisture regimes on tree growth and nutrient dynamics in a mango orchard soil. Apart from the biometrical and quality characteristics, fertigation regimes may influence the spatio-temporal variations in soil moisture content, nutrient dynamics in soil as well as plant tissues (Bhriguvanshi *et al*., 2012b). Pan evaporation based irrigation scheduling thus are region/site specific and nutrient doses also vary from soil to soil based on their inherent content and fruit crop specific (Shirgure *et al*., 2004).

Mango is considered as an important economic alternative in the Malihabad region of Uttar Pradesh, India where large scale commercial orchards of Dashehari mango are established. 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. However, there are some water availability restrictions in the semiarid areas where the production of mango fruits is more intense (Adak *et al*., 2013). For this reason, the water resources in such areas must be appropriately used in irrigation management. Under drip irrigation system, water application is regulated in accordance with crop physiological cycles. Thus, changes in soil water levels associated with different soil moisture regimes are essential for better understanding of yield-limiting factors and forms a basis for future soil water management strategies. The present study was, therefore, aimed to study the effect of different fertigation regimes on spatio-temporal variation in soil water content, nutrient dynamics, mango productivity and quality in subtropical region of Lucknow, Uttar Pradesh.

2. MATERIALS AND METHODS

A field experiment was laid out on mango in the experimental research farm of Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow (26.54^{0}N Latitude, 80.45^{0}E Longitude and 127 m amsl), Uttar Pradesh, India. The field had fairly level topography with 1% slope. The climate is subtropical with a dry hot summer and relatively cool winters. May and June are the hottest months with mean daily maximum temperatures varying from 36 to 39°C, while January is the coldest month with mean daily minimum temperatures ranging from 6.6 to 7.9°C. The mean annual rainfall is around 1000 mm, of which 80% is received during the southwest monsoon from July to September; the rest is received through the 'Western Disturbances' from December to February. Mean daily pan evaporation ranges from 1.8 (January) to maximum 8.75 mm day^{-1} (May), mean wind velocity varies from of 2.71 km hr^{-1} in December to 9.08 km hr^{-1} in June. The soil of the experimental site belongs to the major group of Indo-Gangetic alluvium with sandy loam texture and proper drainage. Taxonomically, the soil is mixed hyperthermic *Typic Ustocrepts*. The experimental soil was sandy loam, with pH ranging from 7.03 to 7.39, EC 0.27ds m^{-1}, bulk density 1.44 g cm^{-3}, water holding capacity 30%, infiltration rate 3.6cm hr^{-1}, organic carbon 0.27% with available P (10.2 mg kg^{-1}) and K (112.2 mg kg^{-1}).

The experiment was conducted in randomized block design with five replications on 30-year old mango cv *Dashehari* planted at spacing of 10 ×10 m during 2010-12. Treatments consisted of different fertigation regimes *viz*., T_1- NPK application in basin irrigation (control), T_2- NPK fertigation from the beginning of September to the end of October, T_3- NPK fertigation at the time of flowering, T_4- NPK fertigation at the time of fruit setting and T_5- NPK fertigation from the beginning of September to second week of May. All trees were fertilized with recommended doses of NPK through urea, DAP and MOP each year. The irrigation was done through drippers (8 l hr^{-1}) on the basis of 60% open pan evaporation (Bhriguvanshi *et al*., 2012a). The trees in basin (T_1) were fertilized with 1000 g N, 500 g P_2O_5 and 1000 g K_2O tree^{-1} during the month of September in 30 cm deep trenches at 2.0 m from the trunk. In rest treatments (T_2 to T_5), 75% of recommended fertilizer dose *i.e.* 750 g N, 375 g P_2O_5 and 750 g K_2O were applied at different stages. N and K_2O were applied through drippers.

Soil samples were collected from the tree basin with vertical depth at 25 cm interval up to 75 cm depth (0-25 cm, 25-50 cm and 50-75 cm) from all the treatments before fertilization each year. Samples were air dried at room temperature and processed through 2 mm sieve and homogenated. Soil organic carbon was estimated using standard wet digestion method. The available Zn, Cu, Mn and Fe contents (DTPA extractable) were estimated by 'Chemito' AA203D model of atomic absorption spectrophotometer as per the standard procedure. Available P of soil was estimated by the Olsen method using spectrophotometer and available K of soil was estimated by extraction with 1 N ammonium acetate at pH 7.0 by AAS. Five to six months old 40 leaf tissues from each treatment were also collected, decontaminated by washing first with tap water, followed by washing in single and double distilled water. Excess water on the surface of the leaves was removed by pressing between the folds of blotting paper and the leaves were dried in an oven at 48^{0}C for 72 hours. After complete drying, the samples were ground in a grinder and used for analysis purpose. Oven dried leaf samples were analyzed for different nutrients by digesting 1 g leaf powder in di-acid mixture (9:4 ratios of nitric acid and perchloric acid) by using standard analytical methods. Phosphorus was estimated by vanado-molybdate colorimetric methods, K and the micronutrients Fe, Mn, Cu and Zn were analyzed by AAS. Soil moisture content (%, vol.) was recorded *in-situ* at a depth of 0-15 and 15-30 cm at monthly interval during 2010-11 at different crop phenological stages using a WET sensor. Fruit yield was recorded at maturity and quality parameters *viz*. TSS, acidity and ascorbic acid were estimated by standard methods. Pooled data were analyzed and mean values of soil water content were used to assess spatial and temporal variability. Univariate analysis was performed on the data set using MS Excel software. Required histograms were generated using SPSS version 12.0 for frequency distribution of soil moisture content.

3. RESULTS AND DISCUSSION

Climatic Conditions during Experimentation

The agroclimatic data (Table 1) revealed that the mean monthly maximum temperature ranged from 19.6 to 38.1^{0}C and minimum temperature varied between 4.5 and 24.9^{0}C during November to June. The maximum relative humidity averaged around 70.9 to 90.9%. A spatio-temporal variation of total monthly rainfall was observed. Higher pan evaporation (5.0 mm day^{-1}) was observed during March onwards. There was no limitation of sunlight during the course of this experimentation as mean monthly bright sunshine hours averaged around 7.1 hrs.

Temporal Variations in Soil Moisture, Fruit Yield and Quality Parameters

There was significant temporal variation in soil water content over the sampling period in the soil. However, the variability was much more governed by the climatic condition during the sampling period as the weather conditions particularly rainfall, evaporation, temperature, solar radiation and wind speed have significant influence on the soil moisture content (Tijani *et al*., 2008). Higher moisture retention was observed in the treatment where NPK fertigation scheduling was applied from beginning of September to second week of May (T_5). In general, 15 to 19% soil water content was recorded during November and December. Higher soil moisture content during this period was due to lower evaporation from the surface soil (Table 1). With the advancement of sampling time towards summer season, average moisture content decreased to 10-12%. This may be because of increase in ambient temperature coupled with higher evapotranspiration from the surface soil layers. This was supported by the pan evaporation data during the sampling period. Higher moisture content in the range of 26-32% in April was due to unseasonal rain (13.8 mm) on 31 March. Data during this period was recorded after proper percolation and drainage. However, in May and June, soil water content decreased from 12-15%. The univariate analysis of soil water content (Table 2 and Table 3) indicated that the variability and range of moisture content was lower in the surface layer as compared to the sub-surface. This may be due to the fact that ploughing of surface layer might have caused homogeneity in the surface layer while the soil in sub-surface was still heterogeneous. However, there was no significant trend in the variability in different sampling times and in different treatments. The histographic analysis (Fig. 1) indicated that higher values of soil moisture content distributed in the range of 10 to 20% with a frequency percentage between 10 and 20. Moreover, it was observed from the graphical presentation of log normal distribution of soil water content data set that the log normal distribution was in higher range from 2.2 to 3.2 with majority of frequency range >5% at surface soil layer (0-15

Table: 1
Monthly average meteorological parameters during soil moisture monitoring period (November, 2010 to June, 2011)

Month	Air Temperature (^{0}C)		Relative Humidity	Bright Sunshine hours	Wind velocity	Total Rainfall	Pan Evaporation
	Max.	Min.	(%)	(hr)	(km hr^{-1})	(mm)	(mm)
Nov.	28.1	13.9	91.9	5.1	1.5	27.6	2.5
Dec.	23.9	5.7	90.1	6.5	1.7	0.0	2.0
Jan.	19.6	4.5	90.7	5.3	2.6	3.6	1.9
Feb.	25.8	9.4	88.0	7.7	2.9	11.0	3.0
March	31.7	13.5	82.3	9.0	3.0	22.3	4.9
April	35.9	17.8	70.9	8.5	3.5	10.2	6.8
May	38.1	23.3	73.4	8.7	4.5	76.8	7.2
June	34.9	24.9	82.3	6.2	4.6	267.5	6.0

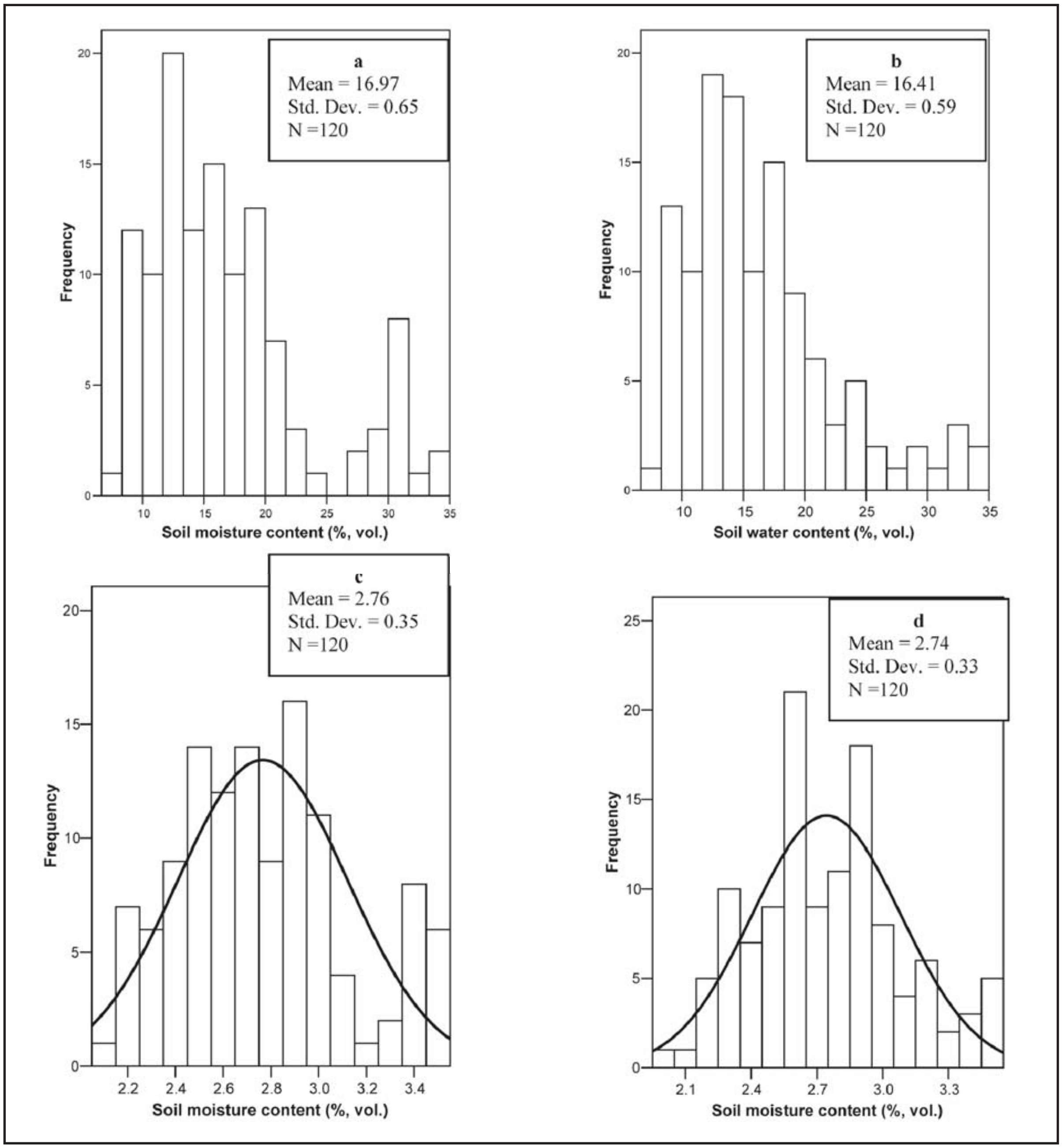

Fig. 1. Frequency distribution of soil water content (%, vol.) in different soil depths a: 0-15 cm and b: 15-30 cm without transformation, c: 0-15 cm and d: 15-30 cm with log normal transformation under different fertigation regimes

cm soil depth) while for the same data set at deeper depths, the frequency showed somewhat restricted distribution. The lowest soil moisture was observed in the treatment (T_1) where water was applied through basin irrigation. This may be due to the fact that basin application caused more seepage loss of water. The highest fruit yield of mango (5.4 t ha^{-1}) was obtained in fertigation with N, P and K from the beginning of September to second week of May (T_5) as compared to control (3.5 t ha^{-1}) (Table 4). Quality parameter like ascorbic acid (35.1 mg 100 g^{-1}) was also higher in T_5 as compared to T_1.

Spatial Variations in Soil Moisture

The knowledge of soil moisture content in the upper soil layer is of utmost importance to assess the hydrological response of soil. In particular, the root zone soil water level is of more concern as it decides the crop's response towards the moisture related stress behaviour. Actually, soil water content is a key state variable responsible for change in hydrological processes occurring within the soil layer over a wide range of spatial and temporal scale (Famiglietti *et al*., 2008). In addition, it controls surface and subsurface drainage and leaching of nutrients and heavy metal contamination to

Table: 2
Univariate analysis of soil water content (%, vol.) at 0-15 cm soil depth

		Mean	SD	Variance	CV%	SE	Skewness	Range
T_1	November	15.8	1.7	3.1	10.4	1.0	1.1	15.3-18.7
	December	16.1	0.6	0.4	3.8	0.1	0.9	15.5-16.8
	January	10.6	1.0	1.0	6.5	0.3	1.6	14.9-16.8
	February	10.8	1.9	3.6	16.7	1.2	-0.3	9.4-13.2
	March	11.5	2.7	7.3	23.5	2.4	0.9	9.1-14.4
	April	28.0	0.6	0.4	2.0	0.1	0.5	31.2-31.4
	May	12.3	1.1	1.2	8.3	0.4	-1.7	12.0-13.9
	June	14.6	3.1	9.4	17.4	3.1	1.7	15.7-21.1
T_2	November	16.8	2.2	4.9	11.1	1.6	1.7	18.4-22.4
	December	17.2	3.9	14.8	22.4	4.9	0.8	13.8-21.4
	January	11.4	2.2	4.7	20.4	1.6	1.5	9.0-13.1
	February	11.2	1.2	1.4	9.7	0.5	0.2	11.2-13.6
	March	11.5	5.2	27.0	40.6	9.0	1.7	9.7-18.8
	April	30.8	0.5	0.2	1.6	0.1	-1.7	30.8-31.7
	May	13.3	3.8	14.7	23.9	4.9	0.6	12.5-20.1
	June	17.6	2.8	8.0	14.3	2.7	-1.4	16.6-22.0
T_3	November	18.9	0.5	0.3	2.7	0.1	-0.6	18.4-19.4
	December	16.4	3.1	9.5	18.7	3.2	-1.7	12.9-18.5
	January	11.1	0.5	0.2	4.0	0.1	0.9	11.0-11.9
	February	11.4	3.2	10.3	25.7	3.4	-0.2	9.2-15.6
	March	11.7	3.3	10.7	28.0	3.6	-1.7	7.9-13.8
	April	31.4	1.9	3.6	6.0	1.2	0.3	29.9-33.7
	May	14.9	3.3	10.8	20.0	3.6	-1.1	12.8-19.2
	June	17.1	1.7	2.8	9.8	0.9	-0.8	15.3-18.6
T_4	November	19.9	3.3	11.0	21.0	3.7	-1.7	12.0-17.9
	December	19.2	1.0	0.9	5.0	0.3	-1.7	18.1-19.8
	January	11.9	1.0	0.9	8.1	0.3	-1.5	10.8-12.6
	February	12.4	1.9	3.4	16.5	1.1	-1.5	9.1-12.6
	March	12.3	2.6	6.5	20.7	2.2	0.2	9.8-14.9
	April	31.6	2.5	6.0	7.7	2.0	0.1	29.2-34.1
	May	16.0	2.4	5.9	19.7	2.0	-1.2	9.6-14.3
	June	19.8	1.3	1.6	8.5	0.5	-1.6	13.2-15.5
T_5	November	21.6	2.9	8.4	13.4	2.8	-1.5	18.3-23.7
	December	20.1	0.6	0.3	2.8	0.1	-1.2	19.5-20.6
	January	15.6	1.9	3.7	17.4	1.2	-1.7	8.9-12.3
	February	12.5	0.6	0.3	5.2	0.1	-0.8	10.2-11.3
	March	12.8	2.7	7.3	23.5	2.4	0.9	9.1-14.4
	April	31.7	2.2	4.7	7.7	1.6	1.7	26.7-30.5
	May	16.4	1.1	1.1	7.1	0.4	1.5	14.1-16.1
	June	22.5	5.9	34.7	26.2	11.6	1.2	17.7-29.1

ground water. The influence of climate variability on temporal dynamics of soil moisture has received attention in recent years. Higher soil moisture may result in higher evaporation and precipitation, and an accurate soil moisture representation can enhance precipitation predictability (Koster *et al*., 2000). Soil moisture information also has potential to improve seasonal precipitation prediction. Timbal and Mc Avaney (2001) suggested that a high inter-annual variability of soil moisture could potentially play a role in affecting Australian seasonal climate forecasts, and Reichle and Koster (2003) found that soil moisture could be important for seasonal prediction of mid-latitude summer precipitation. Henceforth, it is essential to have thorough understanding of soil moisture behavior for irrigation scheduling, precision agriculture, flood forecasting, and hydrological modeling *etc.*

Table: 3
Univariate analysis of soil water content (%, vol.) at 15-30 cm soil depth

	Months	Mean	SD	Variance	CV%	SE	Skewness	Range
T_1	November	16.8	2.7	7.2	13.9	2.4	1.7	17.7-22.5
	December	15.6	3.1	9.7	19.9	3.2	1.0	12.9-19.0
	January	12.8	2.1	4.2	13.2	1.4	-0.2	13.5-17.6
	February	10.0	2.6	6.9	20.2	2.3	-1.6	10-14.9
	March	9.4	2.2	4.7	19.9	1.6	0.6	8.9-13.2
	April	26.0	3.7	13.5	14.1	4.5	1.6	23.4-30.2
	May	13.1	1.3	1.6	9.6	0.5	1.6	12.2-14.5
	June	16.4	2.8	7.7	16.9	2.6	-1.1	13.3-18.7
T_2	November	19.0	1.2	1.4	6.2	0.5	1.1	18.0-20.3
	December	14.5	1.6	2.4	10.7	0.8	0.1	13.0-16.1
	January	11.0	2.7	7.1	24.1	2.4	1.7	9.3-14.1
	February	12.0	1.5	2.1	12.1	0.7	0.3	10.6-13.5
	March	10.9	2.9	8.2	21.9	2.7	-0.4	10.1-15.8
	April	30.3	4.7	22.4	15.6	7.5	-1.3	25.0-34.1
	May	14.4	1.3	1.6	8.7	0.5	0.1	13.2-15.7
	June	17.9	1.6	2.5	8.8	0.8	1.4	16.7-19.7
T_3	November	18.2	2.5	6.4	13.9	2.1	0.7	15.9-20.9
	December	14.2	3.7	14.0	26.3	4.7	-1.7	9.9-16.7
	January	12.2	2.1	4.3	17.0	1.4	-1.6	9.8-13.6
	February	11.8	0.5	0.2	4.2	0.1	0.0	11.3-12.3
	March	11.3	3.6	12.8	31.7	4.3	1.4	8.5-15.3
	April	28.3	1.7	2.9	6.0	1.0	-1.2	26.4-29.7
	May	14.9	3.6	12.8	24.0	4.3	-1.5	10.8-17.5
	June	17.5	2.4	5.6	13.5	1.9	-1.7	14.8-18.9
T_4	November	19.4	6.2	38.4	36.9	12.8	-0.6	10.2-22.5
	December	20.4	2.3	5.2	11.1	1.7	1.6	18.8-23.0
	January	11.7	1.9	3.4	15.9	1.1	0.4	9.9-13.6
	February	11.8	1.2	1.3	9.7	0.4	0.1	10.7-13.0
	March	11.9	2.6	6.9	27.9	2.3	1.1	7.2-12.3
	April	23.7	4.7	22.4	15.4	7.5	-1.1	25.4-34.6
	May	14.1	2.9	8.5	20.7	2.8	1.7	12.3-17.5
	June	14.2	0.7	0.5	4.9	0.2	1.7	13.8-15.0
T_5	November	22.7	2.0	4.1	8.9	1.4	-1.7	20.4-24.0
	December	20.2	0.3	0.1	1.3	0.0	-1.5	19.9-20.4
	January	15.6	2.8	7.6	21.5	2.5	-0.2	10.0-15.5
	February	13.0	0.9	0.8	8.9	0.3	-1.3	9.0-10.7
	March	13.1	2.6	6.8	21.9	2.3	-1.7	8.9-13.6
	April	30.6	7.2	52.3	30.5	17.4	1.3	17.9-31.8
	May	15.8	2.1	4.2	13.0	1.4	-1.4	13.5-16.6
	June	19.7	6.8	46.2	34.6	15.4	1.1	14.0-27.2

The soil water content also depends on the textural class of soil. It was reveled from the mechanical analysis that the orchard soil had low clay content (6%) and maximum sand portions. Therefore, knowledge of soil water retention in orchard soils of semi-arid region with sandy in nature is important information from view point of site-specific water management in fruit crops. Consequently, measurement of site-specific soil water content in orchard soils is on high demand in view of improving fruit quality, water use efficiency and water productivity apart from increasing water retention and evaluating moisture extraction pattern (Holzapfel *et al*., 2000; Spreer *et al*., 2007; Melgar *et al*., 2008). Panigrahi and Srivastava (2011) found that soil moisture fluctuations under different irrigation regimes were negligibly affected at both 45 cm and 60 cm depths, suggesting the confinement of effective root zone of the citrus plants within top 30 cm soil profile. The fluctuation of soil moisture content at 0-30

Table: 4
Effect of soil moisture and nutrient regimes on yield and quality of mango

Treatment	Fruit yield ($t\ ha^{-1}$)	TSS (^{0}Brix)	Acidity (%)	Ascorbic acid ($mg\ 100g^{-1}$)
T_1	3.58	19.96	0.16	31.67
T_2	3.71	19.93	0.15	33.93
T_3	4.03	20.30	0.15	32.80
T_4	4.72	20.00	0.16	31.67
T_5	5.44	19.80	0.13	35.06
CD(p = 0.05)	0.06	0.003	0.001	0.02

cm depth in 100% irrigation was relatively higher during April to June than November to March, indicating higher tree water consumption during April-June over November-March. Likewise Vijayakumar *et al*. (2011) observed that soil moisture content was higher near the drip emitters in sandy loam soil grown with onion than increasing its distance from the emitters. In perennial fruit crops like mango, vigorous growth at the initial years of tree growth is a function of moisture regime at the root zone. At the initial stage of plant establishment; root and shoot growth required optimum soil moisture level maintained in the soil for its rapid growth. However, after attaining a desirable canopy, it needs a calculated amount of irrigation water to meet out its ET demand. Therefore, incremental use of irrigation water required to maintain the optimum soil moisture level within the rhizosphere. Oyedele and Tijani (2010) observed that the spatial distribution of the percent clay content of the topsoil (0-30 cm) showed similarity with the water stored in the soil profile. This indicated that the soil texture is also an important underlying factor responsible for the spatial variability of the soil water.

Fertigation Effect on Yield and Quality

The highest yield in T_5 treatments may be because of the fact that nutrients along with irrigation water were applied at all the critical crop phenological stages. The observed differences in yield in other treatments may be because of the different fertigation regimes applied. Effect of fertigation on spatial variations in soil moisture content, nutrient distribution, yield and quality of several fruit crops were reported across different agro-ecological regions (Bharambe *et al*., 2001; Prasad *et al*., 2003). Panwar *et al*. (2007) observed improvement in 'Dashehari' mango yield and quality under fertigation regimes as against conventional methods of surface irrigation application in Pantnagar condition. The irrigation applied at the estimated volume of water in $l\ day^{-1}\ plant^{-1}$ and 100% of normal dose (380g: 380g:380g) through fertigation recorded highest fruit set, retention, yield and quality parameters. Under subtropical condition of Lukcnow region, Bhriguvanshi *et al*. (2012) revealed that yield improvement under fertigation regimes was in the range of 8.97 to 13.56 $t\ ha^{-1}$ while without fertigation the range narrowed down to 8.13 to 9.5 $t\ ha^{-1}$. Even under high density mango plantation system, Srinivas and Venugopalan (2012) under Bangalore condition recorded higher fruit number and fruit yields with 50% Evaporation Replenishment rate (ER) as compared to 25% ER. Ofcourse a non-significant yield differences between 100% Recommended Dose of Fertilizer (RDF) and 75% RDF were revealed. The response surface models fitted to the yield data indicated an optimum ER of 42% and RDF of 62%. Similarly, Joshi *et al.* (2012) inferred that drip irrigation at 100% of estimated irrigation water requirement + 125% RDF

Table: 5
Soil organic carbon content, available P and K in fertigated Dashehari Mango

Treatments	Soil depth (cm)	Soil organic carbon (%)	Available P ($mg\ kg^{-1}$)	Available K ($mg\ kg^{-1}$)
T_1	0-25	0.52 ± 0.04	18.23 ± 0.67	130.07 ± 8.40
	25-50	0.43 ± 0.04	13.43 ± 2.10	119.12 ± 19.65
	50-75	0.30 ± 0.02	12.07 ± 1.50	92.23 ± 1.86
T_2	0-25	0.53 ± 0.04	18.90 ± 1.92	159.47 ± 43.95
	25-50	0.45 ± 0.15	13.23 ± 0.91	129.80 ± 27. 21
	50-75	0.32 ± 0.05	12.33 ±1.65	97.87 ± 19.11
T_3	0-25	0.47 ± 0.14	18.57 ± 0.78	140.67 ± 14.50
	25-50	0.38 ±0.03	15.93 ± 2.82	118.20 ± 5.76
	50-75	0.28 ± 0.03	12.20 ± 0.96	94.63 ± 6.69
T_4	0-25	0.53 ±0.04	18.87 ± 2.58	156.60 ± 1 7.54
	25-50	0.37 ± 0.02	14.47 ± 0.29	142.83 ± 16.62
	50-75	0.28 ±0.02	14.90 ± 4.33	112.33 ± 15.88
T_5	0-25	0.57 ±0.06	18.93 ± 1.94	181.83 ± 16.37
	25-50	0.45 ± 0.06	15.03 ± 1.60	152.33 ± 12.12
	50-75	0.27 ± 0.04	11.70 ± 0.72	121.13 ± 8.52

± Values indicate standard deviation.

along with mulch was better for improving plant growth parameters, yield and quality fruits.

Soil and Leaf Nutrient Distribution

The results pertaining to the nutrient distribution in soil and leaf tissues showed better nutrient levels in all the treatments as compared to the control. Soil organic carbon content ranged between 0.27-0.57%, available P ranged between 11.7-18.93 mg kg^{-1} and K 92.23-181.83 mg kg^{-1} across different treatments (Table 5), of course the highest availability of these nutrients were recorded in T_5 treatment as compared to control (T_1). Available micronutrients (Fe, Mn, Cu and Zn) had showed improvement in T_5 over T_1 with highest values as Zn (0.75 mg kg^{-1}), Cu (3.63 mg kg^{-1}), Mn (8.53 mg kg^{-1}) and Fe (11.07 mg kg^{-1}) (Table 6). Leaf tissues were found in optimum range (Table 7) with the highest content as 0.25% P, 0.94% K, 29.67 mg kg^{-1} Zn, 35.33 mg kg^{-1} Cu, 68.33 mg kg^{-1} Mn and 262.33 mg kg^{-1} Fe. A variation in soil and leaf tissues nutrient status was reported and mostly improvements in their content were observed in fertigation regimes as compared to non-fertigation regime. Panigrahi and Srivastava (2011) concluded that the leaf macro (N,P,K) and micro (Fe, Mn, Cu and Zn) nutrients registered the maximum content at full irrigation followed by 70% of the full irrigation regimes. The irrigation and fertilizer application with or without mulch increased the nutrient status in 'Dashehari' mango leaves whether applied singly or in combination with regard to N, P and K (Panwar *et al.*, 2007). Bhriguvanshi *et al.* (2012b) recognized the importance of maintaining optimum soil moisture and carbon storage in the root zone through drip irrigation system. Further, indicated that irrigation water applications through drip were essentially required to maintain the highest micronutrient availability and distribution within the soil profile as well as horizontally away from the tree trunk. The degree of variability in micronutrient dynamics as a function of soil moisture could be explained to the tune of 51-69% for Zn, 72-82% for Cu, 41-68% for Mn and 68-74% for Fe as compared to lower degree in basin irrigation. Irrigation given to the replenishments of 60% of USWB open pan evaporation along with 750 g N $tree^{-1}$ was the best moisture levels in maintaining micronutrients dynamics at 0-50 cm soil depths at 1 m horizontal distances from tree trunk than that at 1.5 m along with highest fruit productivity (Bhriguvanshi *et al.*, 2013).

Table: 6
DTPA extractable soil micronutrients (mg kg^{-1}) in fertigated Dashehari Mango

Treatments	Soil depth (cm)	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})
T_1	0-25	0.27 ± 0.01	2.83 ± 0.93	7.03 ±0.97	6.63 ±1.63
	25-50	0.21 ±0.01	2.47±0.49	5.50 ±2.86	6.27 ±1.53
	50-75	0.17± 0.02	1.90 ±0.44	3.93±0.85	4.83 ±1.15
T_2	0-25	0.39 ±0.03	3.83 ±2.00	7.97 ±7.13	8.50 ± 2.63
	25-50	0.27 ±0 .01	2.10±0.44	7.50 ±2.34	6.67 ± 2.60
	50-75	0.22 ±0.02	1.53±0.42	6.93±2.00	4.87 ±1.50
T_3	0-25	0.45 ±0.12	1.80±0.36	8.17±1.14	8.73 ±2.30
	25-50	0.33 ±0.09	1.67±0.55	7.53± 1.16	4.83± 0.61
	50-75	0.25 ±0.08	1.27 ±0.42	6.47±0.84	3.87 ±0.06
T_4	0-25	0.57 ±0.06	2.80 ±0.56	7.23 ±0.29	10.57 ± 2.72
	25-50	0.47 ±0.09	2.30 ±0.44	6.00±0.69	6.80 ± 0.36
	50-75	0.41 ±0.02	1.47 ±0.12	4.70 ±2.17	4.90 ±1.15
T_5	0-25	0.75 ±0.16	3.63 ±1.21	8.53± 3.09	11.07± 2.84
	25-50	0.55 ±0.09	2.63 ±1.57	7.07 ±2.08	8.97 ± 1.14
	50-75	0.47 ±0.04	1.70 ± 0.72	6.03±0.96	6.27 ± 2.35

± Values indicate standard deviation.

Table: 7
Effect of Fertigation regimes on leaf nutrient content in mango cv Dashehari

	Phosphorus (%)	Potassium (%)	Zinc (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Fe (mg kg^{-1})
T_1	0.22 ± 0.01	0.80 ± 0.11	21.67 ± 3.21	14.67 ± 17.21	42.67 ± 8.39	208.67 ± 7.94
T_2	0.22 ± 0.02	0.92 ± 0.07	23.33 ± 2.08	15.00 ± 22.50	66.00 ± 8.72	214.67 ± 53.20
T_3	0.22 ± 0.02	0.89 ± 0.14	24.33 ± 1.53	18.67 ± 6.24	49.67 ± 9.07	222.33 ± 33.65
T_4	0.22 ± 0.01	0.80 ± 0.04	26.67 ± 2.52	20.33 ± 8.96	41.00 ± 3.61	243.00 ± 32.72
T_5	0.25 ± 0.04	0.94 ± 0.06	29.67 ± 1.53	35.33 ± 2.52	68.33 ± 3.79	262.33 ± 47.44

± Values indicate standard deviation.

Correlation of Yield and Quality Parameters with Soil and Leaf Nutrients

Pearson's correlation coefficients between soil nutrients with yield and quality parameters showed significant variations among them as some were significant at 1% level of significance and others were at 5% level (Table 8). It was inferred from the analysis that the yield is positively correlated with soil organic carbon (SOC) content (r = 0.994**) and soil micronutrients (r = 0.898* to 0.994**). In contrast, TSS was non-significantly correlated with these parameters. Available soil K and P was positively and significantly correlated with yield and acidity as well as ascorbic acid content (r = 0.865* to 0.921**). Soil micronutrients were also significantly correlated with acidity and ascorbic acid content (r = 0.892* to 1.00**). SOC content was positively correlated with available nutrients at 1% level of significance. Micronutrients as a function of SOC was statistically significant and positively correlated (r = 0.729** to 0.999**) indicating the fact that soil organic carbon is of important aspects in orchard soil management in order to have better micronutrient dynamics for improvement of yield and quality parameters. Soil micronutrients were positively correlated among themselves. Regarding correlation of foliar nutrients with the yield and quality parameters, it was inferred that leaf micronutrients were positively correlated with yield yet mostly non-significantly correlated with quality values (Table 9).

4. CONCLUSIONS

It was concluded from this study that *in-situ* soil moisture variations over space and time scale existed in the mango orchard soil. Higher moisture content was recorded in the surface layer (0-15 cm) and it decreased with the depth. Higher moisture retention was observed in the treatment where fertigation was applied during September to second week of May. Lower moisture content (9-10%) was recorded during flowering period indicated that a stress condition is required for flowering in mango. The analysis of univariate statistics of soil water content indicated that the variability and range of moisture content was lower in the surface layer as compared to the lower soil layers. It was also inferred that spatio-temporal variations in soil water content impacted flowering, productivity and fruit quality significantly by different soil moisture regimes. Nutrient distribution showed improvement in all the treatments as compared to the control. Soil organic carbon content of 0.57% and available micronutrients (Fe, Mn, Cu and Zn) showed improvement in T_5 over T_1 with highest values as Zn (0.75 mg kg^{-1}), Cu (3.63 mg kg^{-1}), Mn (8.53 mg kg^{-1}) and Fe (11.07 mg kg^{-1}). Leaf tissues were found in optimum range with respect to P, K and Zn, Cu, Mn and Fe. Yield is positively correlated with soil organic carbon (SOC) content (r = 0.994**) and soil micronutrients (r = 0.898* to 0.994**). Micronutrients as a function of SOC was statistically significant and positively correlated (r = 0.729** to 0.999**). Fertigation with N, P and K from the beginning of September to second week of May coinciding all the critical stages wherein nutrient were applied in split doses has been found optimum for enhancing fruit yield and quality along with nutrient dynamics of Dashehari mango in this region.

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Table: 8
Pearson's correlation matrix of yield and quality parameters with soil nutrients under different fertigation regimes in Dashehari mango

	Yield	TSS	Acidity	Ascorbic acid	SOC	P	K	Zn	Cu	Mn	Fe
Yield	1										
TSS	NS	1									
Acidity	.873(*)	.762(*)	1								
Ascorbic acid	.978(**)	NS	-.871(*)	1							
SOC	.994(**)	NS	1.000(**)	.989(**)	1						
P	.865(*)	NS	.877(*)	.921(**)	.774(**)	1					
K	.879(*)	NS	.902(*)	.873(*)	.736(**)	-.235	1				
Zn	.994(**)	NS	1.000(**)	.989(**)	.999(**)	.769(**)	-.733(**)	1			
Cu	.991(**)	NS	.997(**)	.993(**)	.993(**)	.815(**)	-.665(**)	.991(**)	1		
Mn	.987(**)	NS	.986(**)	.988(**)	.945(**)	.851(**)	-.616(*)	.939(**)	.951(**)	1	
Fe	.898(*)	NS	.892(*)	-.907(*)	.729(**)	.710(**)	-.372	.712(**)	.774(**)	.746(**)	1

Table: 9
Pearson's correlation matrix of yield and quality parameters with foliar nutrients under different fertigation regimes in Dashehari mango

	Yield	TSS	Acidity	Ascorbic	P	K	Zn	Cu	Mn	Fe
Yield	1									
TSS	NS	1								
Acidity	NS	NS	1							
Ascorbic	NS	NS	-.939(*)	1						
P	NS	NS	-.913(*)	NS	1					
K	NS	NS	NS	.954(*)	NS	1				
Zn	.990(**)	NS	NS	NS	NS	NS	1			
Cu	.941(*)	NS	NS	NS	.959(**)	NS	.934(*)	1		
Mn	NS	NS	NS	.974(**)	NS	.942(*)	.412	.512	1	
Fe	.999(**)	NS	NS	.497	NS	.328	.994(**)	.932(*)	.338	1

** Correlation is significant at 0.01 level (2-tailed). * Correlation is significant at 0.05 level (2-tailed). NS- non-significant

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