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Standardisation of soil volume wetting for drip irrigation in mango (*Mangifera indica* L.,)

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ABSTRACT

Field experiments were conducted in mango for four years during 2017-2020 at ICAR-Indian Institute of Horticultural Research to standardise optimum soil volume wetting for drip irrigation. Wetting soil volume upto 70% recorded higher mean fruit yield of 34.8 kg/plant (9.68 t/ha)and with further increase in the level of soil volume wetting irrigation (upto 80%), there was a decline in the mango yield (7.40 t/ha). Similarly, significantly increased response was observed in fruit weight upto 70% soil volume irrigation (226 g) although there were no significant differences in the TSS of the fruit. Significantly higher water use efficiency was observed for 30% soil volume wetting irrigation (274.1 kg/m^3) and further no significant differences were observed in water use efficiency between 50% and 70% soil volume wetting irrigations indicating that in areas of water scarcity, it is enough to scheduling the irrigation only upto 50% soil volume wetting in mango for economising the water (232.1 kg/m^3).

Keywords: Mango yield, scheduling irrigation, soil volume wetting, water use efficiency

INTRODUCTION

A properly designed and operated drip irrigation system has to supply the water amount required by the crop and should also wet enough soil volume. The wetting patterns which develop from dripping water onto the soil depend on discharge and soil type. Two of the key factors in the design of micro-irrigation systems to obtain the maximum benefits are the amount of water used and the volume of soil to be wetted.

The partial soil wetting pattern by micro irrigation requires assessment of the percentage of soil volume that is wetted (Sne, 2006). Distance between emitter on lateral pipe and distance of lateral pipes from each other should be determined based on the degree of wetted soil diameter by emitters. Duration of irrigation also depends on the fact that at what time after commencement of irrigation, the wetting front reaches depth of plant's root or a multiple of it. Distance of outlets, discharge rate and time of irrigation in drip irrigation have to be determined so that volume of wetted soil is close to volume of plant's root as much as possible. This is because volume of wetted soil surface and moisture depends on soil texture and layering, soil homogeneity, dripper flow rate, primary moisture of soil, consumption water and land slope. A truncated ellipsoid is assumed to best represent the geometry of the wetted soil volume under an emitter. The restricted volume of the wetted soil under drip irrigation and depth-width dimensions of this volume are of considerable practical importance. The volume of the wetted soil represents the amount of soil water stored in the root zone, its depth dimension should coincide with the depth of the root system while its width dimension should be related to the spacing between the emitters and lines. The parameters which influence the wetted soil volume are the available water holding capacity of the soil and the peak daily crop water use representing specific field conditions. The irrigation interval and the management-allowed deficit are additional parameters which affect the wetted volume and could be changed depending on crop sensitivity as well as water and irrigation equipment accessibility (Li *et al*., 2004).

Irrigation water applied should be adequate for crop water use in irrigation interval. The applied water should not be beyond crop root zone to avoid deep percolation. Although the wetted soil is based on soil type, flow rate, and crop water use, the horizontal and vertical water movements are related to both emitter flow rate and soil intake rates. As such there is a need to optimise the wetted volume taking into account soils, crop, crop stage and seasons.

Mango is the main fruit crop of India and is extensively cultivated under rain fed conditions (68%) with wider spacing without much inputs. At present mango is cultivated in an area of 22, 93,000 ha with a production of 2, 07, 98,000 MT, the productivity being 9.66 t/ha (Anon. 2019). Most of the fruit development of on-season mango fruits takes place during the dry season and farmers have to irrigate mango trees to ensure high yields and good quality. Mango responds well to irrigation especially during fruit set to fruit development. Mango fruit production and quality at fruit growth stage were significantly affected under different irrigation water amounts. Variation in soil water content not only had effects on fruit size, but also on fruit yield (Wei *et al*., 2017). Deficit irrigation strategies are needed to increase water use efficiency and solve the problem of fruit weight reduction during development (Srikasetsarakul *et al*., 2011). Further, the amount of water to be irrigated and the per cent soil volume to be wetted need to be standardized to a given crop situation for enhanced water use efficiency especially under scarce situations. Keeping these points in view, efforts were made to standardise the optimum soil volume wetting irrigation for mango.

MATERIALS AND METHODS

Field experiments were conducted for four years during 2017 to 2020 at ICAR- Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru located at a latitude of 13°8’12"N and a longitude of 77°29’45"E, to standardize the optimum wetted soil volume for irrigation in 18 years old mango (variety Raspuri) spaced at 6m x 6m. The maximum temperature during the experimental period ranged from 24^0C to 36^0C and the minimum temperature ranged between 10^0C to 22^0C. The period between March to May are the warm months with higher temperatures and evaporation while the period between November to January were the cooler months with low temperature and evaporation. The average relative humidity was higher during September and October months. The average rainfall of the location is around 850 mm with two peak periods of rainfall during June-July and September-October months.

Pre-experimental soil had a pH of 4.73 with moderate salts (1.00 dSm^{-1}). The organic carbon content of the soil was good (2.91 %). The available nitrogen (471.4 kg/ha), available phosphorus (23.8 kg/ha) and the available potassium content of the soil was on higher side (350 kg/ha).

The experiment involved comparison of three levels of soil volume wetting irrigation (30%, 50% and 70%) with normal drip irrigation (80% soil volume wetting) as control in RBD design with six replications. The mango crop was maintained with recommended package of practices except for irrigation.

The evaporation data was collected from USWB Class A open pan evaporimeter of meteorological observatory situated in the experimental farm of ICAR-IIHR. Irrigation scheduling was done based on pan evaporation data as per the treatments coinciding with the period from fruit set to fruit development stages.

The volume of the active root zone (soil volume) was arrived by excavating the moist soil carefully (without damaging the roots) around the base before experimentation in the representative plants. Plastic barriers were introduced to the required length and depth of the root zone to demarcate the required per cent wet and dry zones. Three different percentages of the surface soil areas were wetted by the use of single (for 30% and 50% soil volume wetting) and double drip laterals (for 70% soil volume wetting). The amount of rain was taken into account and irrigation paused or reduced accordingly. Total water applied was measured and water applied per tree was calculated based on application time and nominal flow rate. The calculated amount of water for each irrigation was either partially wetted or fully wetted in the root zone depending on the treatment. An irrigation level of 80% ER was fixed based on the results of earlier experiments in mango and water use was calculated to wet the required per cent soil volume in the active root zone based on the wetted area basis as per the treatments.Soil moisture variations were monitored both in dry and wet zones periodically through gravimetric method.

Mango was applied with recommended FYM with a fertilizer dose of 730g N, 180g P_2O_5 and 680g K_2O per plant per year and the crop was managed with recommended package of practices except for irrigation. Plant hoppers were controlled using

Imidacloprid 0.3% and powdery mildew with wettable Sulphur. All the growth and yield parameters were recorded in mango each year. The canopy volume in mango was computed as per standard procedure (Mark *et al*., 2002).

At harvest, yield was determined separately for each tree in alltreatments by the use of a mechanical balance. Water use efficiency (kg fruits $m^{-3}$of water applied) was worked out based on the total water applied through drip irrigation according to FAO recommendations (Doorenbos and Kassam, 1979).

Dropped fruits under all trees in the experiment were collected, counted and weighed. Fruit drop was recorded periodically in number and weight. After harvest the number of all dropped fruits per tree and all harvested fruits were added up to estimate the total fruit retention. The retention rate was calculated as the percentage of fruits attached to the tree at harvest as compared to the calculated initial fruit set.

The mean data was analysed as per standard statistical procedures (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Soil moisture

The moisture studies in the root zone during different periods indicated that there exist significant variations in the soil moisture across the treatments. In the wet zone, the soil moisture increased with increase in the per cent volume of soil irrigated. The highest soil moisture in the wet zone (14.5 %) was recorded with 80% soil volume wetting with a record of 179.9% increased moisture over the dry zone. It was noticed that even with 50% soil volume wetting, the per cent soil moisture difference in the wet zone was over 158.3 % as compared to dry zone.The higher moisture with increased level of irrigation meeting higher volumes of soil may be attributed to the fact that increasing the water application rate allowed more water to distribute in horizontal direction, while decreasing the rate allows more water to distribute in vertical direction for a given volume applied (Li *et al*., 2004). Moreshet (1983) attributed this to the differences in the water depletion as well to the root density distribution pattern between the partially irrigated and that of the fully irrigated one.

Plant growth in mango

The growth parameters in general increased upto 50% soil volume wetting and declined thereafter. Further at 80% soil wetted volume irrigation,significantly lower canopy spread of the plant was observed compared to lower levels of soil volume wetting suggesting that the growth in mango is not favoured much with irrigation above 70% soil volume wetting. Vellame (2015) attributes this to the plant acclimation which is caused by an increase in root concentration in the irrigated area. After a period of acclimation, if the entire root system is wetted, soil water extraction becomes proportional to the percentage of wetted area after a short period of time.

Fruit retention in mango

The fruit retention in mango was significantly influenced by different wetted volumes of irrigating the

Table 1 : Mean soil moisture variation in dry and wet root zones in mango basin

Irrigation treatment	Soil moisture in wet zone (%)	Soil moisture in dry zone (%)	% increase in soil moisture in wet zone over dry zone
30% soil wetted volume irrigation	7.71	3.06	152.0
50% soil wetted volume irrigation	11.96	4.63	158.3
70% soil wetted volume irrigation	12.77	5.01	154.9
80% soil wetted volume irrigation	14.50	5.18	179.9
S.Em±	1.05	0.52	
C.D (P=0.05)	3.35	NS	

Table 2 : Percent wetted soil volume irrigation in influencing the plant growth characters in mango

Treatment	Plant height (m)		Canopy volume (m^3)		Girth (cm)		Primary branches/plant		Secondary branches/plant	
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
30% soil wetted volume irrigation	3.20	3.34	35.64	31.98	64.38	70.00	3.00	3.00	3.38	3.38
50% soil wetted volume irrigation	3.70	3.98	53.06	45.94	64.13	67.75	4.00	4.00	2.95	2.94
70% soil wetted volume irrigation	3.52	3.70	46.10	37.74	67.75	70.25	2.50	2.50	3.30	3.30
80% soil wetted volume irrigation	3.44	3.58	38.24	34.22	63.50	67.25	2.75	2.75	3.05	3.04
S.Em±	0.19	0.19	4.10	4.50	3.38	3.90	0.42	0.42	0.27	0.28
C.D (P=0.05)	NS	NS	12.79	NS	NS	NS	NS	NS	NS	NS

soil with increase in the retention as the percent soil wetting increased with irrigation although the trend was not continuous. Significantly higher fruit retention (49.3 %) was observed at 70% soil volume wetting irrigation which although was found at par with 50% soil volume wetting irrigation (47.2%), differed significantly from the other two levels. The increase in fruit retention with increased moisture levels may be attributed to the reduction in fruitlet drop as a consequence of favourable moisture conditions. These differences may also be attributed to the accumulation of abscisic acid in buds at floral initiation in optimizing leaf water potential and sap flow besides optimizing carbohydrate availability and cytokinin in sustaining differentiation activity in growing buds (Makhmale Sandip *et al*., 2015). Similar observations of maximum fruit retention at harvest stage and delayed maturity in the mango trees with irrigation was also observed by Malshe *et al*., (2020).

Yield attributing characters and the fruit yield

The number of mango fruits per plant increased significantly with increase in soil volume wetting irrigation upto 70% (191.9 fruits/plant) decreasing thereafter suggesting that mango responds only upto this level of soil moisture. Higher fruit number with 70% soil volume wetting irrigation may be attributed to higher fruit retention with reduced fruit drop owing to favourable soil moisture conditions at the critical phase. Morshet *et al*., (1983) also observed that there was a considerable difference in flower abscission between irrigation levels especially at the beginning

Table 3 : Mean fruit retention and fruit number per plant in mango as influenced by different wetted soil volume irrigation during different years

Treatment	Fruit retention in plant (%)				Fruit no. /plant				
	2017	2018	2019	Mean	2017	2018	2019	2020	Mean
30% soil wetted volume irrigation	38.9	39.7	47.9	42.2	120.6	205.7	136.6	65.9	132.2
50% soil wetted volume irrigation	41.2	36.1	38.8	38.7	124.2	198.7	155.3	131.5	152.4
70% soil wetted volume irrigation	44.2	38.2	59.1	47.2	154.5	214.0	230.4	168.8	191.9
80% soil wetted volume irrigation	45.3	37.8	64.7	49.3	66.6	177.0	169.8	146.7	140.0
S.Em±	2.8	3.7	2.8	1.6	18.4	22.7	18.5	25.5	11.91
C.D (P=0.05)	NS	NS	8.7	4.73	56.1	NS	56.2	NS	36.23

Table 4 : Mean fruit yield as influenced by percent soil volume wetting irrigation in mango

Treatment	Fruit yield (kg /plant)					Fruit yield (t/ha)				
	2017	2018	2019	2020	Pooled Mean	2017	2018	2019	2020	Pooled Mean
30% soil wetted volume irrigation	22.1	36.6	21.8	12.0	21.4	6.13	10.17	6.05	3.32	5.93
50% soil wetted volume irrigation	22.4	34.9	28.3	25.0	25.8	6.21	9.68	7.87	6.95	7.15
70% soil wetted volume irrigation	33.7	40.2	45.9	30.4	34.8	9.35	11.18	12.76	8.43	9.68
80% soil wetted volume irrigation	12.2	31.7	31.2	31.5	26.6	3.38	8.79	8.66	8.73	7.40
S.Em±	3.5	3.8	4.0	4.7	2.0	0.97	1.06	1.11	1.30	0.56
C.D (P=0.05)	10.7	NS	12.2	14.2	6.1	2.96	NS	3.38	3.96	1.70

of the flowering season. The flower abscission rate in the partially irrigated trees was higher than in the fully irrigated trees while the abscission of fruitlets was lesser in the partially irrigated treatment.

The mean fruit yield per plant increased significantly with increase in soil volume wetting irrigation upto 70% decreasing there after indicating the graded response to moisture levels in mango. Significantly higher mean fruit yield of 34.80 kg/plant (9.68 t/ha) was recorded with 70% soil volume wetting irrigation. This suggests that it is worth giving irrigation to meet 70% level of evaporation demand in areas where water is not scarce. The results also suggests that with further increase in the level of soil volume wetting irrigation (upto 80%), there was a decline in the mango yield (7.40 t/ha) indicating that beyond 70% of soil volume wetting, it is a luxury consumption for the plant. The increase in mean fruit yield with 70% soil volume wetting irrigation over the control (80% soil volume wetting) was 26.1 per cent indicating the deleterious effects of excess irrigation in mango that too with loss of precious irrigation water (24.5%). Earlier studies in mango also revealed that meeting 70% evaporative demand is the best for higher fruit yield and quality (Srinivas *et al*., 2016).

Fruit weight and TSS

The number of fruits rather than the fruit size influences the total yield. Higher fruit yield and favorable fruit size distribution are counteracting and the exact control of both parameters by means of irrigation seems to be difficult. While there is a negative correlation between the number of fruits onthe tree and the average fruit size, the influence of irrigation on fruit size remains important.

Significantly increased response for irrigation in mango fruit size was observed upto 70% soil volume irrigation (226 g) and decreased there after suggesting that beyond this level, the rate of increase in fruit size is only marginal. Lesser fruit weight at lower levels of irrigation may be attributed to the water stress for the full growth of the fruit. Noitsakis *et al.,* (2016) also inferred that higher level of water stress was observed when 50% irrigation water of fully watered pomegranate plants was applied resulting in a significant decrease in mean fruit weight and diameter.

The TSS in mango fruit was although not significantly influenced by different irrigation wetted volumes of soil, relatively higher T.S.S. of 18.84^0 B was observed at 50% as compared with 80% (17.76^0 B) although found at par with rest of the treatments. Further, this may be attributed to the ability of mango to survive short periods of water deficits as a result of drought tolerance that reduces vegetative growth allowing better penetration of light into the canopy.

Water use efficiency

A perusal of the amount of water used / ha during different years for each of the treatment showed that there was a considerable difference across the treatments. The amount of water used / ha under 80% of soil wetted volume was substantially higher (78.7 m^3/ha) as compared to 30%, the latter depicting a saving of 67.5 % water. Similarly, 50% wetted soil volume irrigation showed a saving of 46.2% water

Table 5 : Mean fruit weight and total soluble solids as influenced by percent soil volume wetting irrigation in mango

Treatment	Mean fruit weight (g)					T.S.S. (^{0}B)				
	2017	2018	2019	2020	Mean	2017	2018	2019	2020	Mean
30% soil wetted volume irrigation	181.4	177.9	156.7	172.9	172.2	19.64	16.66	18.16	18.3	18.2
50% soil wetted volume irrigation	183.5	178	181.7	185.4	182.2	19.40	17.96	20.52	17.44	18.84
70% soil wetted volume irrigation	218	192.8	197.4	183.5	197.9	17.98	17.76	19.32	19.28	18.58
80% soil wetted volume irrigation	214.3	179.7	183.2	230.2	201.8	18.54	15.84	17.48	19.12	17.76
S.Em±	13.71	6.873	4.69	18.01	7.5	0.79	0.48	0.72	0.52	0.28
C.D (P=0.05)	NS	NS	14.27	NS	22.7	NS	1.49	NS	NS	NS

Table 6 : Water use efficiency in mango (over four years) as influenced by different levels of per cent soil volume wetting irrigation

Treatment	Water used (m^3/ha)					Mean water used (litres/ plant)	Savings in water (%)	WUE (kg/m^3)				
	2017	2018	2019	2020	Mean			2017	2018	2019	2020	Mean
30% soil wetted volume irrigation	25.28	33.18	34.73	8.9	25.52	91.8	67.5	242.3	306.6	174.3	373.3	274.1
50% soil wetted volume irrigation	41.90	54.84	57.67	14.9	42.33	152.3	46.2	148.2	176.5	136.4	467.3	232.1
70% soil wetted volume irrigation	58.98	76.71	81.03	20.8	59.38	213.6	24.5	158.6	145.7	157.5	405.8	216.9
80% soil wetted volume irrigation	77.03	95.15	112.75	29.7	78.70	283.1	-	43.9	92.4	76.8	293.7	126.7
S.Em±	-	-	-		-	-	-	23.3	16.8	20.1	93.3	27.0
C.D (P=0.05)	-	-	-		-	-	-	70.8	51.0	61.1	-	82.2

compared to normal (80% soil wetted volume) irrigation indicating that by following the 50% soil volume wetting, nearly double the area of the crop can be irrigated.

Significant variations were observed in the mean water use efficiency across the treatments. Higher water use efficiency was observed for 30% soil volume wetting irrigation (274.1 kg/m^3) differing significantly with other levels suggesting that more yield could be obtained per unit amount of water used with the treatment. Further, as the per cent soil volume wetting irrigation increased, the water use efficiency decreased drastically. This may be attributed to the fact that evaporation is minimised by restriction in wetted soil area and such reduction is influenced by the number of days after the beginning of partial irrigation, atmospheric evaporative demand and plant phonological stage (Vellame *et al.*, 2015).

It was noted that there was non-significant differences in the WUE between 50% (232.1 kg/m^3) and 70% soil volume wetting irrigation (216.9 kg/m^3) indicating that in areas of water scarcity it is worth irrigating only upto 50% of soil volume wetting so that we can also save another 21.7% water. Spreer *et al.* (2009) also inferred that water use efficiency was always significantly higher in the deficit irrigation treatments as compared to the control. Further, Wei *et al.* (2017) also concluded that when the soil moisture content was controlled at about 65±70% of the field water moisture capacity, water demand in the growth and development of mango could be ensured and maximum production efficiency of irrigation and the best quality of fruit could be achieved.

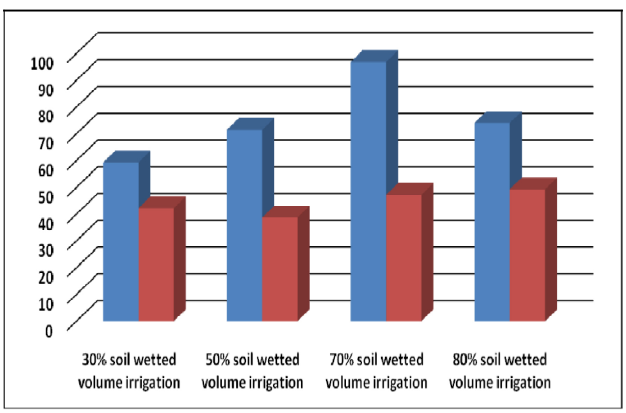

Fig 1. Mean fruit yield and water use efficiency in mango (over four years) as influenced by different levels of per cent soil volume wetting irrigation

CONCLUSION

Wetting soil volume upto 70% recorded higher mean fruit yield of 34.8 kg/plant (9.68 t/ha) and with further increase in the level of soil volume wetting irrigation (upto 80%), there was a decline in the mango yield (7.40 t/ha). Similarly, significantly increased response was observed in fruit weight upto 70% soil volume irrigation (226 g). Significant differences were not observed in water use efficiency between 50% and 70% soil volume wetting irrigations indicating that in areas of water scarcity, it is enough scheduling the irrigation only upto 50% soil volume wetting in mango for economising the water (232.1 kg/m^3).

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