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EVALUATION OF IRRIGATION METHODS AND IRRIGATION SCHEDULING FOR *MELIA DUBIA CAV.*

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ABSTRACT

An experiment to identify the appropriate method of irrigation and to study the effect of irrigation schedule on *Melia dubia* grown for commercial purposes under industrial forestry was conducted on the farm of the College of Agricultural Engineering and Technology, Navsari Agricultural University, Dediapada, from the year 2017 to 2023. The region lies in South Gujarat Medium Rainfall Zone II, having well-drained clay loam soils. Irrigation methods used in this study were drip irrigation and check basin method of irrigation. The irrigations through Drip were scheduled on alternate days at 0.6 (T_1), 0.8 (T_2), 1.0 (T_3) and 1.2 (T_4) Pan Evaporation Fraction (PEF), while check basin (T_5) method of irrigation consisted of irrigation in basins of sizes 2m top width and 1.7m bottom width with 0.15m height, irrigated at weekly interval. The height of the ridge was decided based on the depth of water ponding during the peak period of water demand, in May and the infiltration rate of the soil, which was determined to be around 6 cm/h. The amount of water was calculated considering weekly cumulative pan evaporation (mm), pan coefficient (0.7), and crop coefficient 0.7 for the first year and 1 for the next four years, until maturity. It was found that drip irrigation is good, but not better than the surface method of irrigation, as Check basins; give better biomass production, 71.59 ±16.88 Kg/tree with 7.19 BCR from 5 years old tree, as roots penetrate till around 2 m, by the time tree reaches its maturity. The recommended irrigation schedule using the check basin method of irrigation is at a weekly interval, with 50 mm, 70 mm, 80 mm, 50 mm, and 30 mm depths, respectively during February, March-April, May-June, October-November, and December-January months. It was also inferred that the cost-benefit analysis of all drip treatments shows> 3.59 BCR, however, the drip system could be very well used in water-scarce areas or in areas where water quality is so poor that surface irrigation may deteriorate soil quality. The study also shows that the CROPWAT model gives a good estimate of the water requirement of *Meliadubia*, with an R2 value of 0.81 in the Agro-climatic situation prevailing in Gujarat, India.

***Key words*:** Drip irrigation, Irrigation scheduling, Industrial Agro-forestry, Meliadubia.

Introduction

Irrigation water requirements and irrigation schedules are available for almost all cereal and horticultural crops grown in different agro-climatic regions of India. However, till now there is negligible literature on irrigation and water management aspects of forest tree species. Natural forests are under grave threat from expanding human population and climate change, but, there is a persistent demand for tree species for specific human needs. Further, forest species require lesser maintenance and labor costs while giving good economic returns in the long run. Industries dealing in paper, pulp, matchboxes, and packaging have a persistent demand for fast-growing trees. To cater to these demands and for diversified farming, progressive farmers have been demanding a package of practices and irrigation schedules for important commercial tree species. Drip irrigation helps reduce water required for irrigation due to the very efficient use of applied water, augments water use efficiency, and eliminates problems like salinity build-up and waterlogging associated with the conventional basin irrigation methods (Çetin *et al.*, 2010; Narayanamoorthy, 2010; Mane *et al.,* 2006, Panigrahi *et al.,* 2012; Panigrahi, 2014; Fadadu and Shrivastava 2020, Jagani *et al.,* 2020). Efficient use of water is highly critical to sustain agricultural production, particularly in the context of declining per capita land and water availability.

Meliadubia Cav. is one of the fast-growing multipurpose tree species gaining foothold in most of India as amenable agroforestry species (Parthiban *et al.*, 2019; Chavan *et al.*, 2022), mainly because it could be harvested for commercial purposes after four years of cultivation (Parthiban *et al.,* 2009; Sinha *et al.*, 2019; Thakur *et al.*, 2023) without any delirious effect on understory crops in agroforestry. Farming and Industrial communities need the package of practices including irrigation, to fetch higher productivity with limited resources. The present study is one such effort on *M. dubia*, which is being introduced in the South Gujarat region. The objectives of the study were to study the effect of drip and surface methods of irrigation on the growth of *M. dubia*and to determine the optimum irrigation schedule *vis-a-vis irrigation* cost economics methods employed.

Material and Methods

Study Site Description

The experiment was conducted from 2017 to 2022 at the College of Agricultural Engineering and Technology, Dediapada, Navsari Agricultural University, Navsari, Gujarat, India. The study site is situated at 21°37’39"N latitude, 73°34’57"E longitude, and an altitude of 169 m above mean sea level (Fig. 1). The climate of the region is classified as tropical; with monsoon rains and occasional rains during winters. The temperature averages 26.9°C, May is the hottest (32.6°C) and January is the coolest (at 21.2°C) month. In general, monsoon commences by

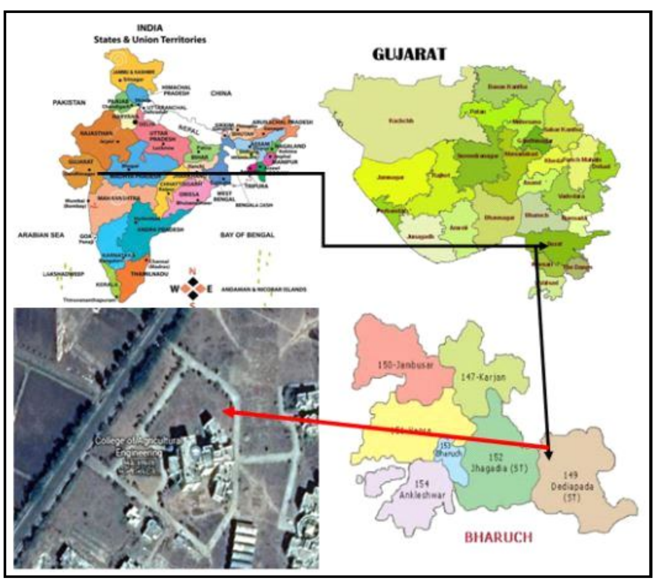

Fig. 1: Location map of irrigation studies on *Meliadubia.*

Table 1: Quantity of water applied during the study period under different irrigation method.

Irrigation method / Year	T_1	T_2	T_3	T_4	T_5
2017-18	2385.07	3180.10	3975.12	4770.14	4293.13
2018-19	7081.39	8851.73	10622.08	12392.43	11153.18
2019-20	2806.47	3508.09	4209.71	4911.32	4420.19
2020-21	3993.52	4991.90	5990.28	6988.66	6289.80
2021-22	4884.44	6105.56	7326.67	8547.78	7693.00
Total water volume	21150.89	26637.38	32123.86	37610.33	33849.30

T_1-Drip Irrigation: 0.8 PEF, T_2-Drip Irrigation: 1.0 PEF, T_3-Drip Irrigation: 1.2 PEF, T_4-Drip Irrigation: 1.4 PEF, T_5-Check Basin: 1.4 IW/CPE (Surface irrigation)

the second fortnight of June and ceases by September end. The rainfall is distributed over the entire *kharif* season, but the concentration of rain is higher during July and August (Lakkad and Shrivastava, 2016). The area receives about 1250 mm of rainfall annually; with the highest precipitation occurring in July. The soil of the experimental site is clay loam, with pH, EC (dS/m), organic carbon (%), available N (kg/ha), P_2O_5 (kg/ha), and K_2O (kg/ha) average values of 7.76, 0.34, 0.50, 210.75, 22.50 and 342.00 (estimated at the time of planting). D*ubia* seedlings were planted at 2 × 2 m spacing (2500 seedlings/ha) adopting Randomized Block Design (RBD). Di-ammonium phosphate @ 15-20 g per tree was applied at the time of plantation.

Irrigation Methods and Water Quantity Applied

The study involves five treatments namely Drip Irrigation: 0.8 PEF (Pan Evaporation Fraction); Drip Irrigation: 1.0 PEF; Drip Irrigation: 1.2 PEF; Drip Irrigation: 1.4 PEF and Check Basin: 1.4 IW/CPE (Surface irrigation), replicated 4 times. In the experiment plot, 16 mm drip laterals were laid out for each tree row (2 m spacing) with the emitter of 8 LPH (Liters Per Hour) capacity. Online drippers were placed alongside the tree row. The uniformity coefficient and distribution uniformity of the drip system were computed from the field data during the study period. A coefficient of uniformity and distribution was worked out for drip irrigation treatments and both were above 90 percent to ascertain uniform application of irrigation water.

The dimensions of the check basin were decided based on-stream size and soil infiltration rate of the field. The length of the check basin was equal to the length of plant rows, the width of the check basin was 2 m top and 1.7 bottom, since tree rows were at 2 m spacing. The ridge height was decided based on the ponding water

Table 2: Average daily water requirement of *Meliadubia* in check basin method.

Year	February	March	April	May	October	November	December	January
2017-18	-	11.3	12.50	13.76	6.22	4.59	3.05	-
2018-19	6.80	11.0	13.69	16.93	12.52	12.29	5.76	3.62
2019-20	7.18	8.4	10.53	10.37	5.69	6.10	4.62	4.93
2020-21	6.97	7.4	8.56	9.03	7.12	5.65	5.37	3.77
2021-22	6.59	8.9	10.26	9.81	6.40	5.31	5.14	6.14
Avg. Daily Evap. (mm)	6.58	9.3	11.11	11.98	7.59	6.79	4.79	4.57
Daily Water Depth (mm)	6.45	10.0		11.74	7.04		4.59	
Weekly Water Depth (mm)	50	70		80	50		30	

depth during the peak period of water demand in May. The quantity of irrigation water applied in each method is given in Table 1. During the experiment period maximum water ponding depth was 8 cm during weekly irrigation in May, while the height of ridges was 15 cm including 7 cm freeboard for water to stand in the basins. The infiltration rate of soil was around 6 cm/h. The amount of water was calculated considering weekly cumulative pan evaporation (mm), pan coefficient (0.7), and crop coefficient 0.7 for the first year and 1 for the remaining period (up to five years). The average daily water requirement of *the Meliadubia* in check basin method was calculated separately and is given in Table 2.

Irrigation Scheduling

The water requirement of *M. dubia* was determined based on pan-evaporation data of the nearest metrological laboratory at Bharuch, Gujarat India.

$$\text{Water requirement (lit./day/plant)} = \frac{Crop\ Area \times PE \times Kc \times Pc \times Watted\ Area}{Eu} \quad (1)$$

Where Crop area = row-to-row spacing (m) * plant-to-plant spacing (m) of the crop, m^2; PE = maximum pan evaporation of the region, mm/day; Pc =pan coefficient, approximately taken as 0.7-0.8; Kc= crop coefficient, the value of which for any crop depends upon foliage characteristics, stages growth of crop, environment and geographical location. The values of Kc range from 0.4 to 1.0 and the average value of Kc is about 0.7; Wetted area = It is the area that is shaded due to its canopy cover when the sun is overhead, which depends upon the stage of growth of the plant. Eu= emission uniformity of drip system, decimal.

The reference evapotranspiration by Penman Monteith equation using CROPWAT (Martin Smith 1996) software was also determined and the correlation coefficient of 0.85 and coefficient of determination of 0.73 was obtained when it was correlated with the reference evapotranspiration obtained by pan evaporation. Irrigation schedules were based on 0.6, 0.8, 1.0, 1.2 PFE for drip irrigation and 1.2 IW/CPE for surface irrigation during the first year, and 0.8, 1.0, 1.2, and 1.4 PEF during the remaining period. Irrigation was stopped during monsoon months *i.e.* from June to September as there was sufficient rainfall to meet the water requirements of the crop.

Estimation of Crop Evapotranspiration With CROPWAT

The daily pan evaporation values were collected and multiplied with a standard constant 0.7 to get the daily reference evapotranspiration. The crop evapotranspiration was then computed by multiplying reference evapotranspiration with the crop coefficient using the given formula.

$$ET_c = ET_0 \times K_c \quad (2)$$

$$\text{Water requirement (lit/plant) per plant} = \frac{ET_C \times Crop\ area \times Wetted\ area}{Eu} \quad (3)$$

The CROPWAT model (Martin Smith 1996) was used to estimate crop evapotranspiration by using available cumulative pan evaporation data and was compared with the actual crop water requirement for all the treatments.

Irrigation Water Requirement and Water Use Efficiency

The total irrigation water requirement as per irrigation level was calculated using the formula: IW = I × ETC. Where IW = Depth of water to be applied (mm); I = level of irrigation (I=1 *i.e.*100% of crop water requirements), ETC = crop evapotranspiration (mm/day). The operating time of drip system treatments was calculated using daily pan evaporation (mm), pan coefficient (0.7), and crop coefficient 0.7 for the first year and 1 for the remaining period. The time of operation of drip irrigation was determined using the following equation.

$$\text{Operation time (min)} = \frac{F \times ECE \times S \times 60}{R \times N} \quad (4)$$

Where, F = Fraction of pan evaporation; CPE = Cumulative pan evaporation; S = Size of plot (m^2); R = Rate of discharge of an emitter (lph) and N = Number of emitters per plot.

Similarly, water use efficiency (WUE) was calculated using formula:

$$WUE_{ij} = \frac{Yg_{ij}}{W_{ij}} \quad (5)$$

Where, WUE_{ij}= Water use efficiency of *M. dubia* under treatment- i and replication-j, (kg/ha-mm); Yg_{ij} = Yield of *M. composita* under treatment- i and replication-j, (kg/ha) and W_{ij}= Seasonal irrigation water applications in treatment- i and replication-j, (mm).

M.dubia Growth and Fresh Biomass Estimation

The height and DBH (diameter at breast height) of every tree were measured regularly during 2020-21, 2021-22 and 2022-23. Standing tree fresh biomass was calculated using the regression equations: Fresh biomass, B=0.0299(HD2) +7.48 (Thakur *et al.*, 2021). Where, B = tree fresh biomass; H= tree height (m); D= DBH (cm) Diameter at breast height. The per-tree biomass was extrapolated to a hectare basis.

Results and Discussion

Effect of Irrigation on Growth and Fresh Biomass (kg/tree) of *M. dubia*

The study revealed that there was no significant effect of irrigation methods on the growth and fresh biomass production of *M. dubia* at the age of 5 years (Table 3). Total water applied by drip system, was minimum in treatment T_1 (5487 ha.mm/ ha) and maximum in T_4 (9602 ha.mm/ ha), whereas, the water application was 8642 ha.mm/ ha in surface irrigated check basin method, T_5 treatment. The highest fresh biomass was obtained in surface irrigated treatment T_5, 71.59 ±16.88 Kg/tree, and the lowest in drip irrigated T_1 52.69a±9.35 Kg/tree, although fresh biomass in all irrigation treatments was at par. The results suggest that if there is sufficient water available then surface irrigation is a better option, but in conditions of water scarcity, drip irrigation could be used for reduced but at-par production of *M. dubia* biomass. The reason for higher production in surface irrigated crops could be because of better root development in the surroundings and deeper soil layers, tree roots take moisture and nutrients from deeper soil layers as well as from the surroundings, *i.e.* from more volume of soil mass. In surface irrigation, water infiltrates to deeper layers as compared to drip irrigation so the roots of the tree go beyond 2 m depth. Whereas, in drip irrigation, the moisture bulb is formed in < 1 m rooting zone, so the concentration of plant roots is in shallow soil layers, around the moisture bulb specifically where the water drips. Also, the region is well drained which allows the growth of tree roots to reach deeper soil layers, thus nullifying the utility of drip irrigation system, especially after the first year when roots penetrate beyond 1 m. The water use efficiency of T_1-Drip Irrigation: 0.8 PEF, T_2-Drip Irrigation: 1.0 PEF, T_3-Drip Irrigation: 1.2 PEF, T_4-Drip Irrigation: 1.4 PEF and T_5-Check Basin: 1.4 IW/CPE (Surface irrigation) was of 24.01, 20.15, 18.39, 16.65 and 20.71, respectively, therefore, Drip Irrigation at 0.8 PEF was found to be the

Table 3: Effect of different irrigation methods on growth fresh biomass production and water use efficiency of *M. dubia* at the age 5 years.

Irrigation methods	Height	DBH	Fresh bio mass (Kg/tree)	Total Water applied (ha.m m/ha)	Water Use Efficiency (Kg/ha mm)
T_1	11.66ᵃ±1.09	9.92ᵃ±1.15	52.69ᵃ±9.35	5486.68	24.01
T_2	11.82ᵃ±0.77	10.43ᵃ±0.96	55.27ᵃ±9.35	6858.35	20.15
T_3	12.55ᵃ±0.52	10.97ᵃ±0.55	60.53ᵃ±6.74	8230.02	18.39
T_4	12.93ᵃ±0.26	11.46ᵃ±0.27	63.94ᵃ±3.77	9601.69	16.65
T_5	12.39ᵃ±0.72	11.34ᵃ±0.89	71.59ᵃ±16.88	8641.56	20.71

T1-Drip Irrigation: 0.8 PEF, T2-Drip Irrigation: 1.0 PEF, T3-Drip Irrigation: 1.2 PEF, T4-Drip Irrigation: 1.4 PEF, T5-Check Basin: 1.4 IW/CPE (Surface irrigation)

Table 4: Cost (INR/ha up to 5 years) of input variables in different irrigation methods used to establish and maintenance of *M. dubia* plantation.

Irrigation method / Year	T_1	T_2	T_3	T_4	T_5
Plantation	41,140	41,140	41,140	41,140	41,140
Irrigation system	38,836	38,836	38,836	38,836	1,000
Labor cost	64,930	64,930	64,930	64,930	64,930
Operating Cost	20437.14	25546.42	30655.71	35764.99	4976.60
Total Cost	1,65,343	1,70,452	1,75,561	1,80,671	1,12,047

T1-Drip Irrigation: 0.8 PEF, T2-Drip Irrigation: 1.0 PEF, T3-Drip Irrigation: 1.2 PEF, T4-Drip Irrigation: 1.4 PEF, T5-Check Basin: 1.4 IW/CPE (Surface irrigation)

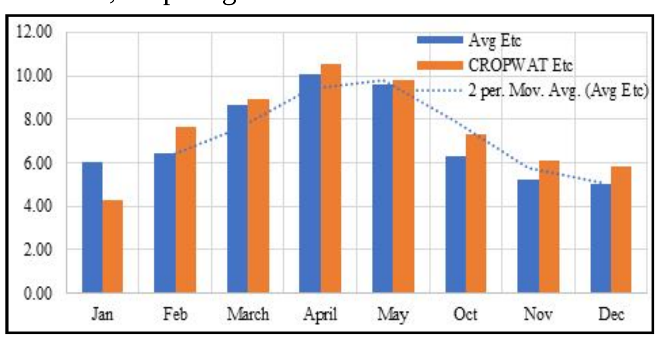

Fig. 2: Actual V/s CROPWAT estimated crop water requirement (mm/d) during fifth year.

Table 5: Economics (in INR) of raising *M. dubia* (at 5 years of age) under different irrigation methods.

Irrigation methods	Gross returns/ha	Net returns	Net returns/year	B:C ratio*	B:C year
T_1	592763	427420	85484	3.59	0.72
T_2	621788	451336	90267	3.65	0.73
T_3	680963	505402	101080	3.88	0.78
T_4	719325	538654	107731	3.98	0.80
T_5	805388	693341	138668	7.19	1.44

T_1-Drip Irrigation: 0.8 PEF, T_2-Drip Irrigation: 1.0 PEF, T_3-Drip Irrigation: 1.2 PEF, T_4-Drip Irrigation: 1.4 PEF, T_5-Check Basin: 1.4 IW/CPE (Surface irrigation)

best in terms of water use efficiency. Thus, surface irrigation, with the check basin method of irrigation has superiority under the Agro climatic conditions prevailing in the Dediapada region. The irrigation should be scheduled at a weekly interval, with 50 mm, 70 mm, 80 mm, 50 mm, and 30 mm depths, respectively during February, March-April, May-June, October-November, and December-January months, in 2×2 m. spaced malabar neem plantations using check basins of size 2m top width and 1.7m bottom width, with 0.15m height, to get maximum fresh biomass.

Economic Feasibility of Irrigation Methods

The cost of cultivation of *M. dubia* under irrigation

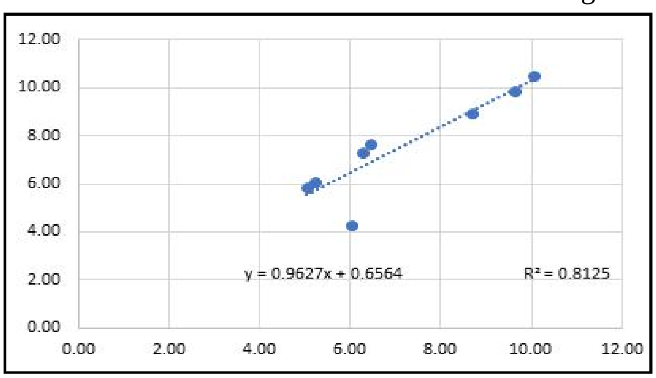

Fig. 3: Correlation of crop water requirement Actual v/s CROPWAT estimated.

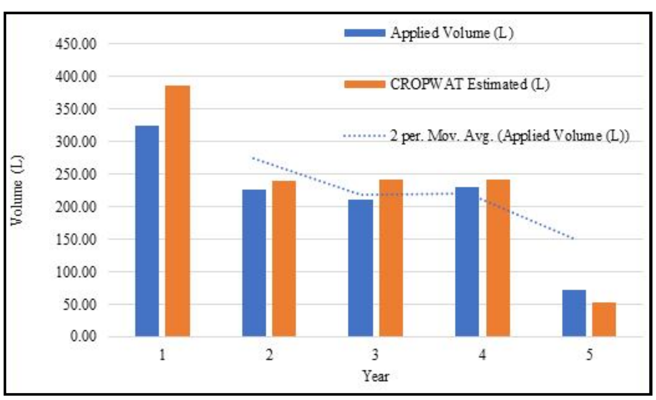

Fig. 4: Irrigation water applied v/s model estimated water demand of *Meliadubia (in L)* for 5-year period.

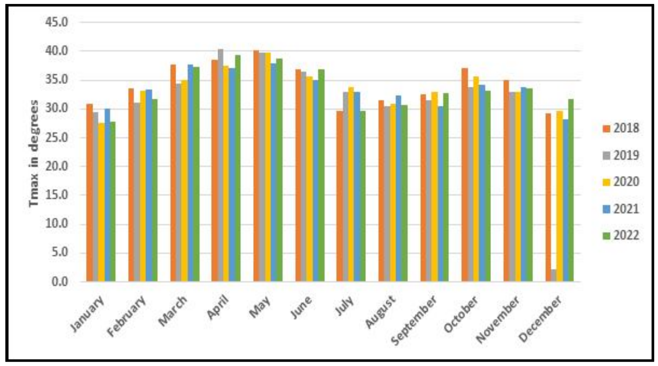

Fig. 5: Maximum temperature (Tmax.) during the growing period of *Meliadubia* (in L).

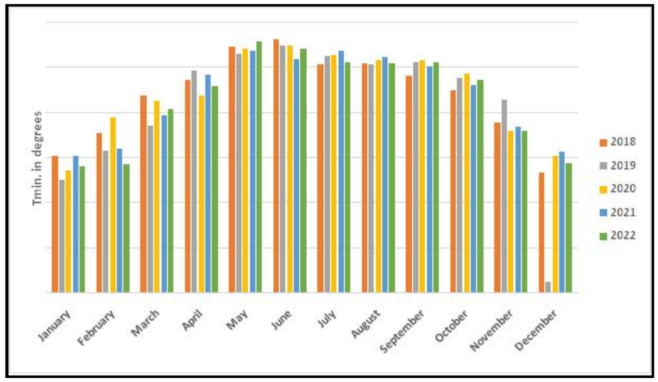

Fig. 6: Minimum temperature (Tmin.) during the growing period of *Meliadubia* (in L).

treatments T_1, T_2, T_3, T_4 and T_5 was INR 1,65,343; 1,70,452; 1,75,561; 1,80,671 and 1,12,047, respectively (Table 4). The maximum gross returns, net returns, and BC ratio amounting to INR 8,05,388; 6,93,341; 1,38,668, and 7.19, respectively were in Check Basin: 1.4 IW/CPE (Surface irrigation) (T_5) irrigation method followed Drip Irrigation: 1.4 PEF (T_4), Table 5. Economic feasibility also shows that the check basin method of irrigation is superior to drip irrigation because the drip system needs high initial investment as well as added operational cost, especially when there are no shortages of water.

CROPWAT Model

The results of the CROPWAT model for the

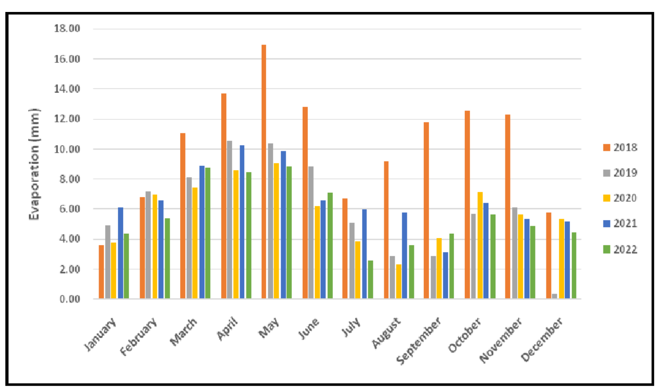

Fig. 7: Pan evaporation during the growing period of *Meliadubia* (in L).

estimation of crop water requirement of *M. dubia* provided a good estimate of water requirement (Fig. 2), with r^2 value of 0.8125 (Fig. 3) in the Agro-climatic situation prevailing at the experimental site. At the age of 5 years (Fig. 2), actual water requirements were found to be less than estimated by CROPWAT, throughout the year, except in January.

The reason for higher actual water demand in the fifth year could be due to unusually higher temperatures in January, resulting in high water requirements as compared to the estimate of CROPWAT. Irrigation water applied and CROPWAT estimated water requirement during the year is illustrated in Fig. 4. After the establishment of the crop, during the first year, the water application as well as the estimated requirement was more due to approximately 50 % below normal annual rainfall in the region, coupled with high maximum (Fig. 5) and minimum temperatures (Fig. 6) during monsoon, resulting in increased crop water demands (Fig. 7). Further, the applied volume of water was slightly less than that estimated by CROPWAT throughout the growing period, except slight increase in the fifth year. Also, the water demands were lower in the fifth year, again due to lower minimum temperatures throughout the fifth year resulting in lower water requirements in the fifth year. Therefore, it could be inferred that due to the close correlation, 0.8125, between actual and estimated water requirements (Fig. 3), CROPWAT could be very well used for estimating the water requirements of *M. dubia*.

Conclusion

The irrigation study on *melia dubia* grown for commercial purposes under industrial forestry for the Dediapada region, which lies in south Gujarat medium rainfall zone ii, having well-drained clay loam soils with ample water availability shows check basin method of irrigation to be the best, yielding 71.59 ±16.88 kg/tree with 7.19 BCR from 5 years old tree. The check basins of sizes 2m top width and 1.7m bottom width with 0.15m height, could be irrigated at a weekly interval, with 50 mm, 70 mm, 80 mm, 50 mm, and 30 mm depths, respectively during February, March-April, May-June, October-November and December-January months. Further, yield from drip irrigation was also at par, but not better than the surface method of irrigation, the cost-benefit analysis of all drip treatments shows> 3.59 BCR, thus drip system could be very well used in water-scarce areas or in areas where water quality is so poor that frequent surface irrigation may deteriorate soil quality. The study also shows that the CROPWAT model gives a good estimate of the water requirement of *melia dubia*, with an R^2 value of 0.81 in the agro climatic situation prevailing in Gujarat, India.

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