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Computation of Irrigation Water Requirements, Its Managements and Calendering In Mulberry Crop for Sustainable Sericulture under Tamil Nadu Conditions

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ABSTRACT *: Water Is Undoubtedly Elixir Of Life. Whether It Be For Irrigation, Drinking & Sanitation Or For The Protection Of Natural Ecosystems & Providing Goods And Services For Growing Populations, Without Water Life On Earth Is Just Impossible And Hence It Is "Lifeline". India Is The Second Largest Silk Producing Country Next To China In The World And Tamil Nadu Occupies The Fourth Position In Raw Silk Production In The Country. Cultivation Of Mulberry Plant Is Mainly For Its Leaves The Sole Food For The Silkworm, Bombyx Mori L. For Commercial Production Of Raw Silk. Mulberry Is Cultivated In About 1.86 Lakh Ha. Area In India. Of The Total Mulberry Area Above 80% Is Under Irrigation Conditions. Where As In Tamil Nadu State Out Of 10,809 Ha. Mulberry Plantation About 95% Of Garden Is Under Irrigated Conditions Reflect The Importance Of Irrigation For Mulberry Crop. As Irrigation Method Adopted In Mulberry By Farmers Is Of Traditional Open Type Applied Without Assessment Of Actual Requirement Of Water For The Crop Which Results In Poor WUE And Huge Water Loss Due To Conveyance, Seepage And Evaporation Etc.,.*
To Find An Efficient Irrigation Water Management System In Mulberry Cultivation, A Field Level Experiment Drawn On Split Split Plot Design In Established Mulberry Garden Under 3'x3' Plant Spacing With Ruling MR2 Variety And High Yielding V1 Popular Variety Being Popularized In Tamil Nadu With Three Types [Furrow (Traditional) Sprinkler & Drip (Modern)] And Three Levels Of Irrigation Water Equal To 100; 70 And 50% Cumulative Epan Scheduled @ 50% SMD In Furrow Method And Same Levels In Both Sprinkler & Drip Scheduled On Alternate Day Was Conducted In Namackal District Of Tamil Nadu During 2004 -'06 For Eight Crops. The Results Of The Experiments Conducted Revealed That Micro-Irrigation Systems I.E., Drip Performed Well At Any Level Of Irrigation Followed By Sprinkler And The Least In Furrow Method. Further Maximum Irrigation Water Savings Of 61.2 And 32.7% Observed Under Micro Irrigation (Drip) As Against Farmers Practice And Actual Irrigation Water Requirement For Mulberry Based On FAO's Modified Penman And Monteith Equation Respectively With Improvement In Water Use Efficiency [WUE] As High As 300% Without Affecting The Sustainable Productivity Of Leaf. The Quality Of Leaf Verified By Bio-Assay And In Terms Of Quality Of Raw Silk And Productivity Revealed The Cost Benefit Ratio Of 1:2.12 And 1:1.99 In V1 And MR2 Mulberry Garden Respectively As Against 1:1.57 Recorded Under Traditional Furrow Irrigation Method. The Status Of Sericulture, Importance Of Irrigation Water Management With Calendaring For Mulberry Crop For Sustainable Development Cope Up With SWOT Analysis Of The Industry In Tamil Nadu Are Discussed In The Paper.

KEY WORDS : *Mulberry Crop; Irrigation Water Management; Water Use Efficiency; Sustainable Productivity; Raw Silk; Cost Benefit Ratio.*

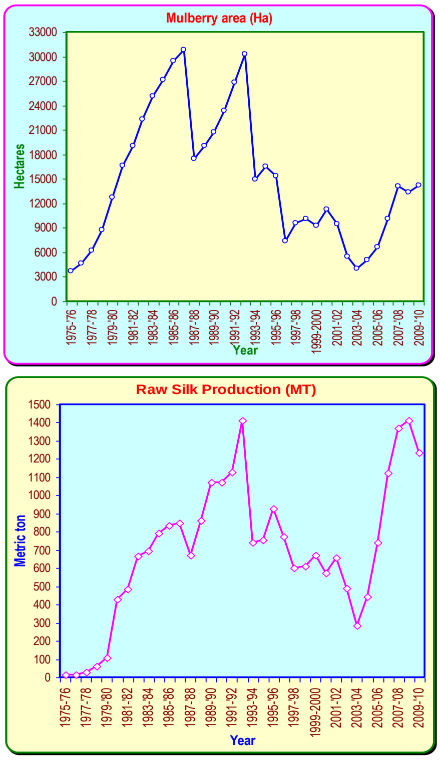
I. INTRODUCTION :

India though occupies 2.4% of land area, it supports for about 16.66% of population with only 4% of water resources in the world. Water demand and supply gap is increasing year after year and shrinkage in availability is posing major threat globally in near future. **Water Resources Consortium** in its recent report (**2009**) stated that **globally**, current withdrawals of about **4500 km^3** exceeds the availability of about **4200 km^3**; by **2030**, the demand is expected to increase to **6900 km^3**; with a slight drop in availability to **4100 km^3** result with a deficit of **40%** and for **India**, the annual demand is expected to increase to almost **1500 km^3**, as against a projected availability of **744 km^3**; a deficit of **50%** (Narasimhan, 2010). India being an agrarian country, its economic growth largely depends on the development of agriculture and agriculture related industries. Southern peninsula of our country mainly depends on rainfall for its water source due to lack of perennial rivers as available in central & northern regions. Tamil Nadu state possesses 3.96% (1.3 crore ha) arable land, 6.08% (7.4 crores) population of the nation with per capita land of 0.208 ha., as against national level 0.32 ha. and 46.89 lakh ha. (36.0%) net sown area and 2.9% land unutilized. The state receives an average annual rainfall of 961.9 mm. in 4 seasons (Anonymous, 2011).

India is second largest silk producing country with a share of 17.5% of raw silk production in the world and is unique in production of all known four varieties of natural silk namely mulberry, tasar, eri and muga. During 2012-’13, a total of 23,679 MT raw silk produced, employment opportunities to 75.96 lakh persons and foreign exchange of Rs. 2,231.08 crores earned for the country through silk goods export by the sericulture industry. Mulberry silk is the most popular one contributing around 80% of total raw silk production of the country from 1.86 lakh ha. mulberry area covering 8.18 lakh sericulture families and 50,918 villages. Of the total mulberry silk of 18,715 MT produced in the country about 97% is produced from the traditional sericulture states namely Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu and Jammu & Kashmir (Anonymous, 2013). About 80 percent of mulberry garden in the country is under irrigated condition which shows the importance of irrigation for the mulberry crop. Silk industry has a long history and is a traditional occupation in Tamil Nadu. During late 1950’s mulberry area in the sate was around 300 acres with very less raw silk production, mulberry cultivation and sericulture activity was restricted in the districts bordering Karnataka state. However the state has earned a prime status of being one of the major silk consuming states in the country since centuries, owing to the best branded design silk sarees production by the traditional artisans from Kancheepuram, Arni, Kumbakonam and Salem with infrastructure facilities >75,000 handlooms and appreciable number of power looms with a total annual consumption around 1,200 MT raw silk. The state has emerged as one of the major silk producing states in the country in late seventies, now occupies 4th position. Presently sericulture is practiced in 29 districts, during 2012-’13 a total of 1,185 MT raw silk produced from 10,809 ha. mulberry by 16,481 farmers accounts for 6.33% production at the national level and production of 575.5 MT bivoltine silk accounts for 29% of quality bivoltine raw silk production of the nation (Anonymous, 2013).

While average renditta (*quantity of cocoons (kg) required for production of one kg raw silk*) of 6.76 during 2012-’13 achieved by the state which is 12.35% less than the national level average renditta of 7.72 and major share on quality bivoltine raw silk production are proven example for wide acceptance and dissemination of improved technologies in the field of sericulture at all levels and rich potential silk weaving clusters in the state are considered as vital strength for the sericulture industry of the state on one side, the other side insufficient irrigation water availability for agriculture purpose in general and for mulberry cultivation in particular due to low rainfall or failure of monsoon or frequent droughts are found to be the only major limiting factor which limits the vertical growth of the industry though the state possesses adequate cultivable land for expansion of mulberry area and many a times to struggle for the maintenance of existing established mulberry area and productivity at farmers level in the field and raw silk production at the state level. (Rajaram *et al.*, 2006) **Fig.1** shows mulberry area and silk production of the state since 1975 for over 3 decades.

Year	Mulberry (Ha)	Raw Silk (MT)
1975-’76	3644	15
1976-’77	4640	16
1977-’78	6228	28
1978-’79	8672	62
1979-’80	12741	106
1980-’81	16583	430
1981-’82	19045	484
1982-’83	22284	666
1983-’84	25118	692
1984-’85	27151	791
1985-’86	29418	833
1986-’87	30750	850
1987-’88	17414	672
1988-’89	19074	864
1989-’90	20719	1072
1990-’91	23311	1072
1991-’92	26811	1128
1992-’93	30304	1410
1993-’94	14921	740
1994-’95	16480	753
1995-’96	15372	925
1996-’97	7377	774
1997-’98	9606	600
1998-’99	10106	611
1999-2000	9279	672
2000-’01	11195	571
2001-’02	9466	655
2002-’03	5460	489
2003-’04	4025	285
2004-’05	5073	443
2005-’06	6614	739
2006-’07	10043	1125
2007-’08	14047	1368
2008-’09	13344	1411
2009-’10	14220	1233



Mulberry requires about 1.5-2.0” acre water per irrigation at an interval of 6 - 12 days depending upon the type of soil and seasons. About eight number of irrigation is required per crop of 65-70 days duration to achieve the maximum leaf yield. Thus the annual requirement of irrigation water for 5 crops is about 75” acre equal to 1875 mm rainfall distributed equally @ 36 mm per week or 5-6 mm per day. But 80% of average annual rainfall of 1,160 mm (Lal, 2001; Gupta and Deshpande 2004) our country is received in 4-5 months and in Tamil Nadu, the average annual rainfall of 961.8 mm. is received in 40-45 days and hence practically, it is not possible to meet the demand of irrigation for mulberry crop by rainfall alone.Further in traditional system of irrigation practice requires more water and manpower; the two major limiting factors becoming scarce and expensive respectively in agriculture sector in general and sericulture in particular attracted the attention of researchers in recent times in the field of water technology and water management. Massive shifting of irrigation from surface water to ground water from the level of about 33% during 1960’s to more than 50% in three decades reduced the ground water level and its quality considerably (Swaminathan, 1994).

Thus water is likely to become critically scarce in coming decades, continuous increase in its demands due to rapid increase in population and expanding economy in India (Ramasamy Iyyar, 2010). Worldwide agriculture is the single biggest drain on water supplies, accounting for about 69% of all use, about 23% of water meets the demands of industry & energy and just 8% goes for domestic & commercial use (Anonymous, 2002). In India, agriculture sector uses about 93% of water whereas industry and domestic & commercial sectors use 3 & 4% respectively (Rakesh kumar *et al.,* 2005). As agriculture is the major area of water consumption in our country, any one speaks of water management; the focus is only on agriculture, even if 10% of water is saved, 14 mha. will benefit additionally. Existence of vast scope for saving water in irrigation, recycling of water for domestic uses and awareness among people on water conservation are the key for water management (Palanisami, 2010). Miyashitha (1986) categorized the various factors contributing successful silkworm cocoon crop as mulberry leaves 38.2, rearing climate 37.8, rearing technology 9.3, silkworm race 4.2, silkworm eggs 3.1 and other factors 8.2%. As mulberry leaves' share for the success of silkworm cocoon crop is high, achievement of quality linked sustainable productivity is inevitable in sericulture.In the above context and in order to achieve maximum **W**ater **U**se **E**fficiency (**WUE**) in mulberry cultivation without compromise on the quality and productivity of leaf and raw silk with the policy of **"M**ore **C**rop and **I**ncome for **D**rop of **W**ater**"** this study was carried out to find way for sustainable sericulture in **T**amil **N**adu.

Materials & methods : The experiment was drawn on Split split plot design as suggested by Sukhatme and Amble (1985) in established mulberry garden under 3'x3' plant spacing with 2 mulberry varieties namely V1(Victory-1) a high yielding variety being popularized and MR2 the ruling variety in the state as M_1 & M_2 with 3 types of irrigation I_1, I_2 & I_3 for furrow (traditional) sprinkler & drip (modern) and 3 levels of irrigation S_1, S_2 & S_3 computation of irrigation water for mulberry crop (Naoi, 1975; 1977) of irrigation water equal to 100; 70 and 50% cumulative E_{pan} value scheduled @ 50% SMD in furrow method; same levels in both sprinkler & drip irrigation and scheduled at alternate day. Thus a total of 18 treatments with 3 replications totaling 54 plots with plant population as suggested by Chaturvedi, H. K. and Sarkar, A. (2000) Annexure : 1 & 2. The experiment was conducted in a demonstration mulberry garden of RSRS., Salem in Namackal district for two years (2004-'06) followed by validation of findings of the experiment at farmers' level for 3 years (2007-'09) in the same locality and the experiment was carried out in 4 crops per annum leaving one crop during peak rainy season due to availability of irrigation water above treatment level during major part of the crop.Simultaneously actual irrigation water requirement for mulberry crop based on crop coefficient approach using the FAO's modified Penman_Monteith formula (Richard G. Allen *et al.,* 1998) as given below :

$$\mathbf{ETo} = \frac{0\;408\,\Delta\,(R\,n - G) + \gamma\,\frac{900\,u2}{T + 273}\,(e\,s - e\,a)}{\Delta + \gamma\,(1 + 0\;34\,u\,2)}$$

$$\mathbf{ETc} = ETo \times Kc$$

ETc = Evapotranspiration of crop; Kc = Crop coefficient constant;

$$\mathbf{Kc} = Kcb \times Ke$$

Kcb : Basal crop coefficient constant; Ke : Soil evaporation coefficient

Where

ETo	Reference evapotranspiration [mm day^{-1}],
Rn	Net radiation at the crop surface [MJ m^{-2} day^{-1}],
G	Soil heat flux density [MJ m^{-2} day^{-1}],
T	Mean daily air temperature at 2 m height [°C],
u2	Wind speed at 2 m height [m s^{-1}],
es	Saturation vapour pressure [kPa],
ea	Actual vapour pressure [kPa],
es-ea	Saturation vapour pressure deficit [kPa],
Δ	Slope vapour pressure curve [kPa $°C^{-1}$],
γ	Psychrometric constant [kPa $°C^{-1}$].

Though all growth and quality parameters of mulberry crop meeting the requirement of silkworm rearing for successful cocoon crop starting from production of leaf and up to raw silk were studied in all crops during the entire experimental period (Annexure : 3-16), important parameters like leaf productivity per unit area, WUE and water savings, leaf quality in terms of quality linked productivity of cocoons and raw silk for sustainable sericulture industry and formulation of suitable Model Irrigation Calendar for Mulberry Crop are covered in this paper.

II. RESULTS AND DISCUSSIONS :

Leaf yield hectare^{-1}year^{-1} (kg) :

Maximum leaf yield of 64377.16 kg.ha.$^{-1}$year^{-1} under the treatment $M_1I_3S_1$ followed by $M_1I_2S_1$ (61938.88), $M_1I_3S_2$ (60687.69) & $M_1I_2S_2$ (55396.20) treatments recorded were statistically significant at CD<P 0.05 level and above the productivity recorded under $M_1I_1S_1$ (50801.48). Increased yield by 26.72 & 21.92% at

same amount of irrigation water used and 19.46 & 9.04% increased productivity with 30% irrigation water savings obtained under drip and sprinkler irrigation respectively compared to the full irrigation under furrow method of irrigation in V_1 mulberry variety. When quantum of irrigation water reduced >30%, the productivity potential did not maintained by the variety. Incase of MR_2, the maximum productivity of 42579.41 $kg.ha.^{-1}year^{-1}$ under the treatment $M_2I_3S_1$ followed by $M_2I_2S_1$ (40746.58), $M_2I_3S_2$ (40291.20), $M_2I_2S_2$ (38123.07) and $M_2I_3S_3$ (36029.38) treatments recorded were statistically significant at CD<P 0.05 level and above the productivity recorded under $M_2I_1S_1$ (35456.86). Increased yield by 20.09 & 14.92% at same amount of irrigation water used, with 30% irrigation water savings 13.64 & 7.52% increased productivity and with overall savings of 50% irrigation water 1.61 & -4.90% increased leaf yield under drip and sprinkler irrigation respectively when compared to the full irrigation under furrow method of irrigation were recorded.Under any combination of treatments drip irrigation (I_3) performed well followed by sprinkler (I_2) and furrow (I_1) methods of irrigation. Similarly yield level performance under full irrigation was higher (S_1) followed by next lower level treatments (S_2) & (S_3) in descending order and between variety, types and levels of irrigation (M x IS) were found statistically significant at CD<P 0.05 level.

From the above it is well understood that the V_1 mulberry variety is having narrow tolerant limit to water stress conditions for maintaining its productivity level i.e., when irrigation water level decreases above 30% the variety could not maintain its potential productivity under any methods (micro-irrigation systems drip & sprinkler) of irrigation. Where as wide adoptability to water stress conditions observed in MR_2 through its productivity potential maintenance with very less quantum of irrigation water application. The variety was able to maintain its productivity potential upto 50% reduction of irrigation water under specific conditions i.e., adaptation of proper water management technologies. Under drip, irrigation water equal to 50% of CPE applied in treatment $M_2I_3S_3$ leaf production of 36029.38 kg was recorded which was 1.61% more than the leaf yield obtained under full irrigation (1.0 IW:DPE) in treatment $M_2I_1S_1$ (35456.86) under furrow irrigation and 34.12% increased yield when compared to the same amount of irrigation water applied in treatment $M_2I_1S_3$, similar response recorded in growth parameters like total shoot length, number of branches & leaves per plant, leaf area & leaf area index. However leaf quality parameters like moisture content & moisture retention capacity; protein & total sugar content studied shown non-significant difference statistically (Table : 2 and Fig. 2-5), similar response was reported by Parikh *et al.,* (1992) in sugarcane. Several authors in several crops reported water savings under drip irrigation with increased productivity without affecting the quality of the product. Sivanappan *et al*., (1974) reported that 84.7% water saving under drip irrigation compared to conventional furrow irrigation without any adverse effects on growth and yield in bhendi and this was confirmed by Sivanappan (1979) in several vegetable crops like tomato, capsicum, okra, pawpaw and bananas with drip irrigation when compared to conventional surface irrigation at 50% SMD.

Ananthakrishna *et al.,* (1995) recommended 80% E_{pan} value of irrigation under drip scheduled alternate day for optimum leaf production in K2 mulberry. Similarly Mishra *et al.,* (1996 and 1997) reported 33% of water savings without affecting the yield under drip in K2 mulberry.Benchamin *et al*., in 1997 reported the existence of positive correlation between the leaf yield and the quantum of irrigation and frequency of irrigation in $Kanva_2$ (K_2) mulberry variety. Drip and sprinkler irrigation save 33 % of irrigation water without loss of leaf yield and quality compared to ridges and furrow method and found drip system more efficient with 10.3 to 14.5% increased leaf yield over furrow system under any quantum of irrigation treatment. Magadum *et al.,* (2004) reported that adaptation of drip irrigation in mulberry cultivation at farmers' level in Karnataka saves a minimum 30% amount of irrigation water without affecting the leaf yield over traditional irrigation.

Water Use Efficiency (WUE) : Maximum water use efficiency (WUE) of 48.99 kg leaf yield $ha.mm^{-1}$ water applied under the treatment $M_1I_3S_3$ followed by $M_1I_2S_3$ (47.25) obtained in V_1 mulberry variety though high, due to the productivity level was much below (>26% & >28% respectively) the potential achieved for the variety both the levels may not be economically viable. Similarly the least WUE under the treatment $M_1I_1S_1$ (26.18) followed by $M_1I_2S_1$ (31.92); $M_1I_3S_1$ (33.17); $M_1I_1S_3$ (33.43) and $M_1I_1S_2$ (33.51) were also found to be economically non viable. The treatments $M_1I_3S_2$ (44.68) $M_1I_2S_2$ (40.78) in V_1 mulberry are found to be economically viable considering the productivity over and above full irrigation (1.0 IW:CPE) under furrow method of irrigation $M_1I_1S_1$ (26.18).

In case of MR_2, the maximum WUE of 37.13 kg leaf yield $ha.mm^{-1}$ water applied with the highest productivity record observed under the treatment $M_2I_3S_3$ with 103.23% more than the WUE full irrigation (1.0 IW:CPE) under furrow method of irrigation $M_2I_1S_1$ (18.27) may be the best choice of method and level (Drip@50%CPE value) of irrigation for the variety. However the next high WUE obtained under the treatment $M_2I_2S_3$ (34.75) may also be found choicest one for the slope & terrain slope land. All other treatments due to less WUE in terms of narrow water stress tolerance and productivity may not be economically found viable. The WUE under different treatments between variety, types and levels of irrigation (M x IS) were found statistically significant at CD<P 0.05 level (Table : 2 and Fig. 6). Muraleedhara *et al.*, (1994) reported CB ratio of 1:1.64 under drip irrigation in K2 mulberry. Productivity increase due to more water savings and additional area coverage with it, improved mulberry varieties / silkworm breed & advancement in technologies have helped to increase the Cost Benefit ratio to a higher level by 1:2.12 & 1:1.99 in V1 & MR2 mulberry varieties respectively in the present study (Fig. 7). Under any combination of treatments drip irrigation (I_3) performed well followed by sprinkler (I_2) and furrow (I_1) methods of irrigation. The WUE and levels of irrigation are inversely proportional i.e., higher the level of irrigation lower the WUE, the high WUE at sustainable productivity level may be considered for recommendation. Ahluwalia *et al*., (1998) reported drip irrigation induced early maturity of sugarcane crop with 38% water saving and 60.9% increased WUE over surface irrigation. Shinde and Jadhav (1998) in sugarcane reported that automatically controlled drip saved water upto 56% and yield increased by upto 52% WUE increased by 2.5 to 3 fold over surface irrigation and mulch reduced water by further 16% than the conventional irrigation. Bains *et al*., (1988) reported in sugar beet crop higher water use efficiency of 912 kg roots /cm. In garlic sprinkler irrigation increased the yield by 13.62% & 5% and WUE by 13.67% & 45.79% higher than the border irrigation of 5 & 7 cm respectively in addition to 28.6% water savings with sprinkler irrigation (Suryawanshi *et al*., 1986). EL-Gindy *et al*., (1996) reported higher crop yield and WUE in vegetable production with sub surface drip irrigation.Ananthakrishna *et al.*, (1995) reported higher WUE in K_2 mulberry in lower level of irrigation water applied and optimal WUE under 80% E_{pan} value of irrigation under drip irrigation. Similarly Benchamin *et al*., (1997) reported better WUE in mulberry under drip & sprinkler irrigation methods.

Cocoon yield (kg) / 10000 larvae reared : Maximum cocoon yield of 19.80 kgs. obtained for 10000 larvae reared under treatments $M_1I_2S_3$, $M_2I_1S_3$ followed by $M_2I_1S_2$ with 19.76 and 19.74 in treatment $M_1I_2S_2$ all at lower levels of irrigation and all yield performance among all treatments in respect of variety, types and levels of irrigation (M x IS) all three factors combined together did not showed any significant difference at CD<P 0.05 level statistically (Table : 2).

Renditta : Minimum renditta of 6.79 in $M_1I_3S_3$ in V1 and 6.77 in $M_2I_3S_3$ in MR2 and the renditta obtained in all treatments were statistically non significant at CD<P 0.05 level (Table : 2). The overall annual renditta for cross breed cocoons of PMxNB4D2 during 1990s was around 9.0 which has improved to a level of 7.0 renditta with PMxCSR2 in Tamil Nadu state during the year 2009-'10 (Anoymous, 2010).

III. WATER STRESS MANAGEMENT & WATER SAVINGS :

Gross irrigation water amount applied in the experiment, farmers' practice and FAO's modified Pennmann-Monteith formula ETc based crop water requirement on crop coefficient approach for mulberry studied showed that upto **45.7 & 61.2%** water used at farmers' practice and **5.9 & 32.7%** water as per FAO's modified Penman-Monteith formula ETc based water requirement for mulberry have been managed to save under drip irrigation in V1 & MR2 mulberry variety respectively with sustainable productivity maintenance very close to the potential leaf yields of the concerned variety and over and above the productivity obtained under full irrigation in furrow method (Table : 1).

Table : 1

Season	Farmers' Practice (mm)	FAO's m P-M equation (mm)	Experiment (cum E_{pan} in mm)		
Level	*Full*	*Full*	*100%*	*70%*	*50%*
Nov. - Jan.	500	225.8	306.4	214.5	153.2
Jan. - Mar.	500	288.5	412.2	288.5	206.1
Mar. - June	500	299.4	427.6	299.4	213.8
June - Aug.	500	284.4	406.2	284.4	203.1
Average	**500**	**288.6**	**388.1**	**271.6**	**194.1**
Water savings Vs. Farmers' practice			**111.9**	**228.4**	**305.9**
		Irrigation water savings (%)	**22.4**	**45.7**	**61.2**
Water savings Vs. FAO's P-M. equation			**-99.5**	**16.9**	**94.5**
		Irrigation water savings (%)	**-34.5**	**5.9**	**32.7**

IV. CONCLUSIONS :

From the results of the detailed studies conducted on various quality aspects tested and confirmed under the experiments, it is concluded as below for the sustainable sericulture in Tamil Nadu :

- Leaf qualities of both V1 and MR2 mulberry varieties are at par and suitable for silkworm rearing for production of cocoons on commercial scale, though the production potentiality of the later variety is far below the former, based on certain preferred characters with the MR2 both the varieties are recommended for cultivation in the state.
- As the potential productivity level of V1, mulberry variety is comparatively very high and its sustainable productivity level could maintain under narrow water stress conditions, the variety is recommended for places where assured irrigation facilities available.
- Whereas MR2 mulberry variety could maintain its sustainable productivity level under wide limit of water stress conditions, the variety is recommended for places where limited irrigation facilities available.
- Based on the highest production potentiality of both V1 and MR2 varieties established under drip irrigation, the drip irrigation method is recommended for both the varieties in mulberry cultivation under Tamil Nadu conditions.
- As the sustainable leaf productivity achieved at reduced rate of irrigation water upto 30 and 50% of CPE value in V1 and MR2 respectively under drip irrigation, the irrigation water amount equal to 70 and 50% of CPE value in drip irrigation scheduled in alternate days are recommended for the respective varieties under limited irrigation water availability and for effective utilization of irrigation water in mulberry cultivation.
- The performance of microsprinkler irrigation in both V1 and MR2 varieties is very close to drip irrigation and the same system may be appropriate for mulberry garden raised in slope terrain land and calcareous soils. Keeping in view of the above a "Model Irrigation Calendar for Mulberry Crop" (MICMC) has been prepared for the benefit of sericulture farmers, sericulture extension field functionaries and stake holders (Table : 3-4).

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Table : 2 mulberry crop performance under different type levels of irrigation water application and silk productivity

Treatments	Growth parameters and leaf productivity							Leaf quality parameters and silk productiity					
	Total Shoot Length Plant^{-1} (cm)	No. of branches plant^{-1}	No. of Leaves branch^{-1}	Leaf Area [cm^2]	Leaf Area Index	leaf yield ha^{-1}yr^{-1}(kg)	WUE	Protein content [%]	Total sugar content [%]	Leaf moisture content [%]	Moisture retention content [%]	Cocoon yield larvae^{-10000} (kg)	Ren-ditta
$M_1I_1S_1$	928.57	7.40	27.94	150.82	3.85	50801.50	**26.18**	23.62	11.11	75.47	83.47	18.88	7.39
$M_1I_1S_2$	822.24	7.40	26.63	134.85	3.28	45513.00	**33.51**	23.61	11.04	75.21	83.72	19.25	7.98
$M_1I_1S_3$	609.68	7.39	24.81	96.43	2.18	32434.50	**33.43**	23.59	10.98	74.79	83.62	19.07	8.48
$M_1I_2S_1$	1014.15	7.44	30.24	184.42	5.12	61938.90	**31.92**	23.64	11.15	75.03	83.75	19.39	6.94
$M_1I_2S_2$	938.04	7.41	28.71	163.61	4.30	55396.20	**40.78**	23.62	11.08	75.25	83.77	19.74	7.36
$M_1I_2S_3$	758.74	7.39	24.90	135.68	3.08	45844.30	**47.25**	23.61	11.02	75.28	83.65	19.80	7.94
$M_1I_3S_1$	1046.60	7.41	30.77	191.85	5.40	64377.20	**33.17**	23.62	11.13	75.61	83.56	19.72	6.79
$M_1I_3S_2$	998.06	7.41	30.28	180.61	5.00	60687.70	**44.68**	23.63	11.07	75.39	83.77	19.73	7.09
$M_1I_3S_3$	788.80	7.39	25.42	141.23	3.27	47537.20	**49.00**	23.62	11.05	75.40	83.74	19.66	7.85
$M_2I_1S_1$	816.17	7.49	30.87	105.27	3.00	35456.90	**18.27**	23.41	10.90	73.82	80.50	19.44	6.91
$M_2I_1S_2$	777.24	7.44	30.09	92.60	2.56	31159.90	**22.94**	23.40	10.85	73.85	83.73	19.76	7.71
$M_2I_1S_3$	752.99	7.44	30.10	79.87	2.21	26863.20	**27.69**	23.40	10.80	73.54	83.68	19.80	7.79
$M_2I_2S_1$	867.18	7.47	32.01	121.05	3.57	40746.60	**21.00**	23.41	10.90	73.91	83.62	19.29	6.80
$M_2I_2S_2$	829.03	7.36	31.65	112.99	3.25	38123.10	**28.07**	23.40	10.81	73.87	83.70	19.64	7.17
$M_2I_2S_3$	783.60	7.33	31.02	99.98	2.81	33719.60	**34.75**	23.38	10.80	73.64	83.88	19.63	7.47
$M_1I_3S_1$	886.32	7.57	32.16	126.97	3.82	42579.40	**21.94**	23.42	10.90	73.47	83.79	19.51	6.77
$M_1I_3S_2$	836.78	7.38	31.56	119.61	3.44	40291.20	**29.66**	23.41	10.86	73.75	83.66	19.53	7.14
$M_1I_3S_3$	792.33	7.31	31.13	107.12	3.01	36029.40	**37.13**	23.40	10.80	73.64	83.74	19.70	7.43
SED	***5.2054***	***0.0171***	***0.2065***	***0.7717***	***0.0348***	***254.8100***	***0.1887***	***0.0142***	***0.0360***	***0.2710***	***1.0350***	***0.0766***	***0.13***
CD at 5%	***11.0297***	***0.0365***	***0.4334***	***1.6115***	***0.0732***	***536.1200***	***0.3980***	***0.0302***	***0.0783***	***0.5799***	***2.1985***	***0.1643***	***0.28***
Significant level	**	**	**	**	**	**	**	*NS*	*NS*	*NS*	*NS*	*NS*	*NS*

Table:3

MODEL IRRIGATION CALENDAR FOR MULBERRY CROP UNDER TAMIL NADU CONDITIONS

Month	MON	TUE	WED	THU	FRI	SAT	SUN	Month	MON	TUE	WED	THU	FRI	SAT	SUN
JANUARY	1	2	3	4	5	6	7	FEBRUARY				1	2	**3**	4
	8	9	10	11	12	13	14		5	6	7	8	9	10	11
	15	**16**	17	18	19	20	21		12	**13**	14	15	16	17	18
	22	23	24	**25**	26	27	28		19	20	21	22	**23**	24	25
	29	30	31						26	27	28				
MARCH				1	2	3	**4**	APRIL	30						**1**
	5	6	7	8	9	10	11		2	3	4	5	6	**7**	8
	12	**13**	14	15	16	17	18		9	10	11	12	13	**14**	15
	19	**20**	21	22	23	24	25		16	17	18	19	20	**21**	22
	26	27	28	29	30	31			23	24	25	26	27	28	**29**
MAY		1	2	3	4	5	6	JUNE				1	2	3	4
	7	8	9	10	11	12	13		5	6	**7**	8	9	10	11
	14	**15**	16	17	18	19	20		12	13	14	15	16	17	**18**
	21	22	**23**	24	25	26	27		19	20	21	22	23	24	25
	28	29	30	31					26	27	28	**29**	30	31	
JULY	30	31					1	AUGUST			1	2	3	4	**5**
	2	3	4	5	6	7	8		6	7	8	9	10	11	12
	9	10	11	12	13	14	15		**13**	14	15	16	17	18	**19**
	16	17	**18**	19	20	21	22		20	21	22	23	24	**25**	26
	23	24	25	26	**27**	28	29		27	28	29	30	31		
SEPTEMBER						**1**	2	OCTOBER	1	2	3	4	5	**6**	7
	3	4	5	6	7	**8**	9		8	9	10	11	12	13	14
	10	11	12	13	14	15	**16**		15	**16**	17	18	19	20	21
	17	18	19	20	21	22	23		22	23	24	25	**26**	27	28
	24	25	**26**	27	28	29	30		29	30	31				
NOVEMBER				1	2	**3**	4	DECEMBER	31					1	**2**
	5	6	7	8	9	10	**11**		3	4	5	6	7	8	9
	12	13	14	15	16	17	18		10	11	12	13	**14**	15	16
	19	20	**21**	22	23	24	25		17	18	19	20	21	22	23
	26	27	28	29	30				24	25	26	27	28	**29**	30

(more appropriate for sandy clay loam soil)

Table : 4

MODEL IRRIGATION CALENDAR FOR MULBERRY CROP UNDER TAMIL NADU CONDITIONS

Type of soil : Sandy clay loam		Non-economic irrigation				Economic irrigation (Sprinkler / Drip)						
		Number	Quantity	Furrow		Irrigation	V_1 Mulberry garden			MR_2 mulberry garden		
Crop No.	Month(s)	of irrigation	of water / irri. (mm)	Average inter.(days)	Total qty. of water ha.mm	schedule & No. of irrign.	Sprinkler	Drip irrigation		Sprinkler	Drip irrigation	
							ha.mm / irrigation		lrs/plant/irri.	ha.mm / irri.		lrs/plant/irri.
1	January	3	28.8	10.3	86.5	alternate day	5.2	5.2	4.2	3.8	3.8	3.0
	February	3	32.5	9.3	97.4		6.5	6.5	5.3	4.7	4.7	3.8
	March	2	32.9	7.8	65.8		7.4	7.4	6.0	5.3	5.3	4.3
Total		**8**	**31.2**	**9.1**	**249.7**	**36.5**	**234.7**	**234.7**	**190.1**	**168.0**	**168.0**	**136.1**
2	March	2	27.8	7.8	55.6	alternate day	7.4	7.4	6.0	5.3	5.3	4.3
	April	5	30.4	6.0	152.2		9.5	9.5	7.7	6.8	6.8	5.5
	May	3	31.8	10.3	95.4		5.8	5.8	4.7	4.1	4.1	3.4
Total		**10**	**30.3**	**7.3**	**303.2**	**36.5**	**285.0**	**285.0**	**230.8**	**204.1**	**204.1**	**165.3**
3	June	3	51.0	10.0	153.0	alternate day	9.6	9.6	7.8	6.9	6.9	5.6
	July	3	33.9	10.3	101.7		6.2	6.2	5.0	4.4	4.4	3.6
	August	1	31.5	7.8	31.5		7.0	7.0	5.7	5.0	5.0	4.1
Total		**7**	**40.9**	**10.4**	**286.2**	**36.5**	**269.0**	**269.0**	**217.9**	**192.6**	**192.6**	**156.0**
4	August	3	28.1	7.8	84.3	alternate day	7.0	7.0	5.7	5.0	5.0	4.1
	September	4	31.7	7.5	126.8		7.9	7.9	6.4	5.7	5.7	4.6
	October	2	32.3	10.3	64.6		5.7	5.7	4.6	4.1	4.1	3.3
Total		**9**	**30.6**	**8.1**	**275.7**	**36.5**	**259.2**	**259.2**	**209.9**	**185.5**	**185.5**	**150.3**
5	October	1	29.0	10.3	29.0	alternate day	5.7	5.7	4.6	4.1	4.1	3.3
	November	3	29.8	10.0	89.4		5.6	5.6	4.5	4.0	4.0	3.2
	December	3	31.4	10.3	94.2		5.7	5.7	4.6	4.1	4.1	3.3
Total		**7**	**30.4**	**10.4**	**212.6**	**36.5**	**199.8**	**199.8**	**161.8**	**143.1**	**143.1**	**115.9**
Grand Total		**41**	**32.4**	**8.9**	**1327.4**	**182.5**	**1247.7**	**1247.7**	**1010.6**	**893.3**	**893.3**	**723.6**

Actual effective rainfall during irrigation schedules are required to be deducted from the actual quantum of irrigation water given above.

Fig. 2 Average Total shoots length / plant under different system of water management in mulberry

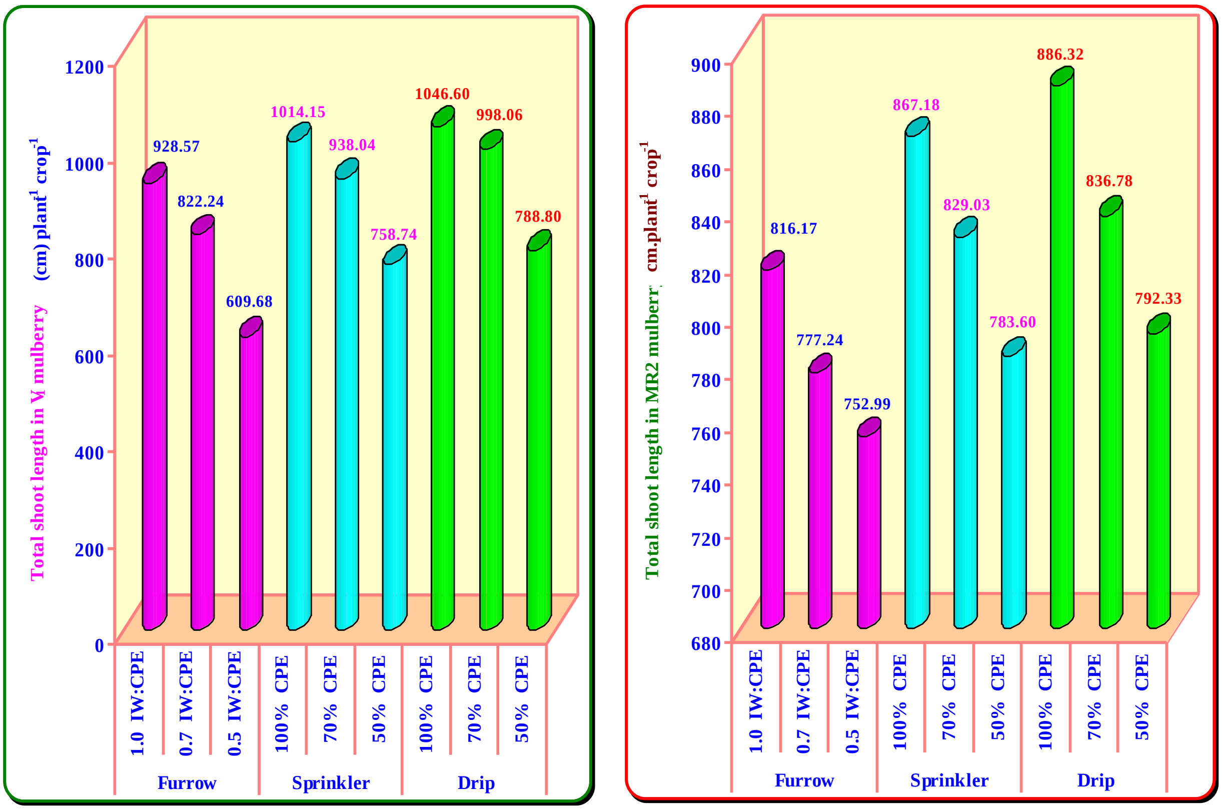


Fig. 2 Average number of leaves / branch under different system of water management in mulberry

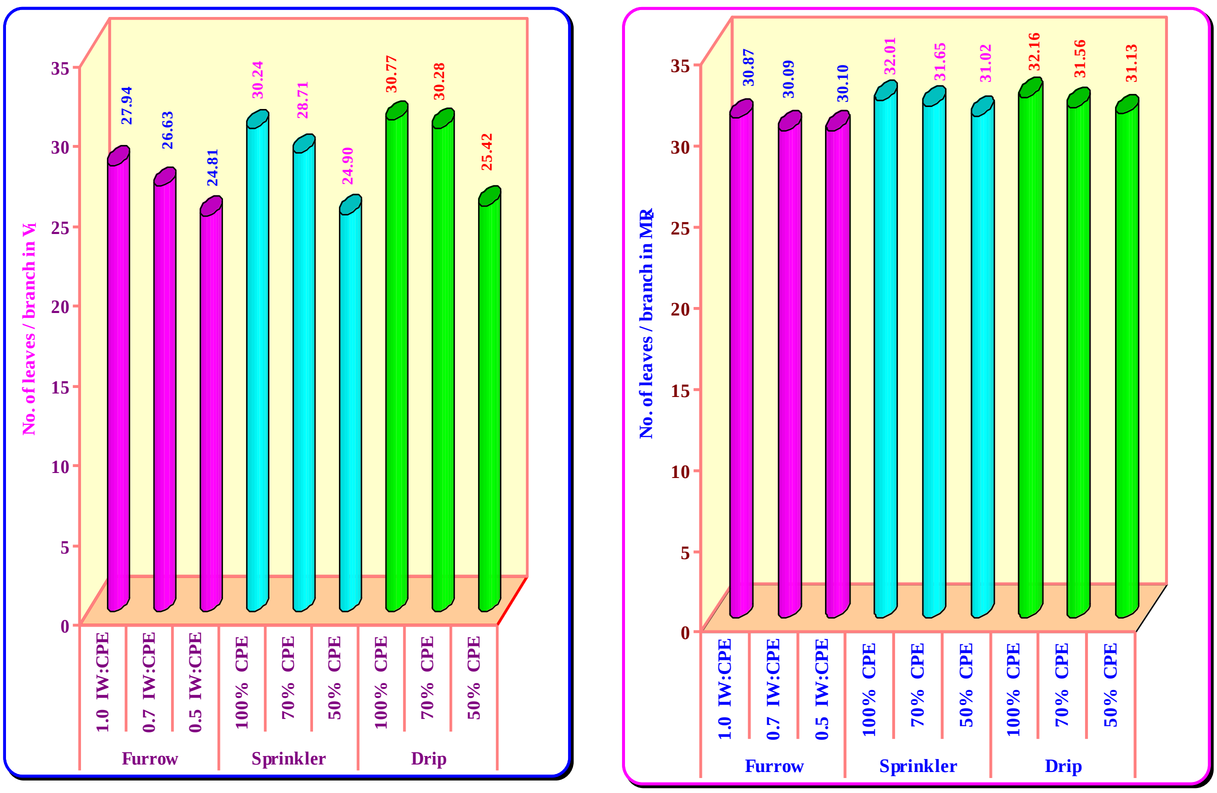


Fig. 3 Average single leaf area under different system of water management in mulberry

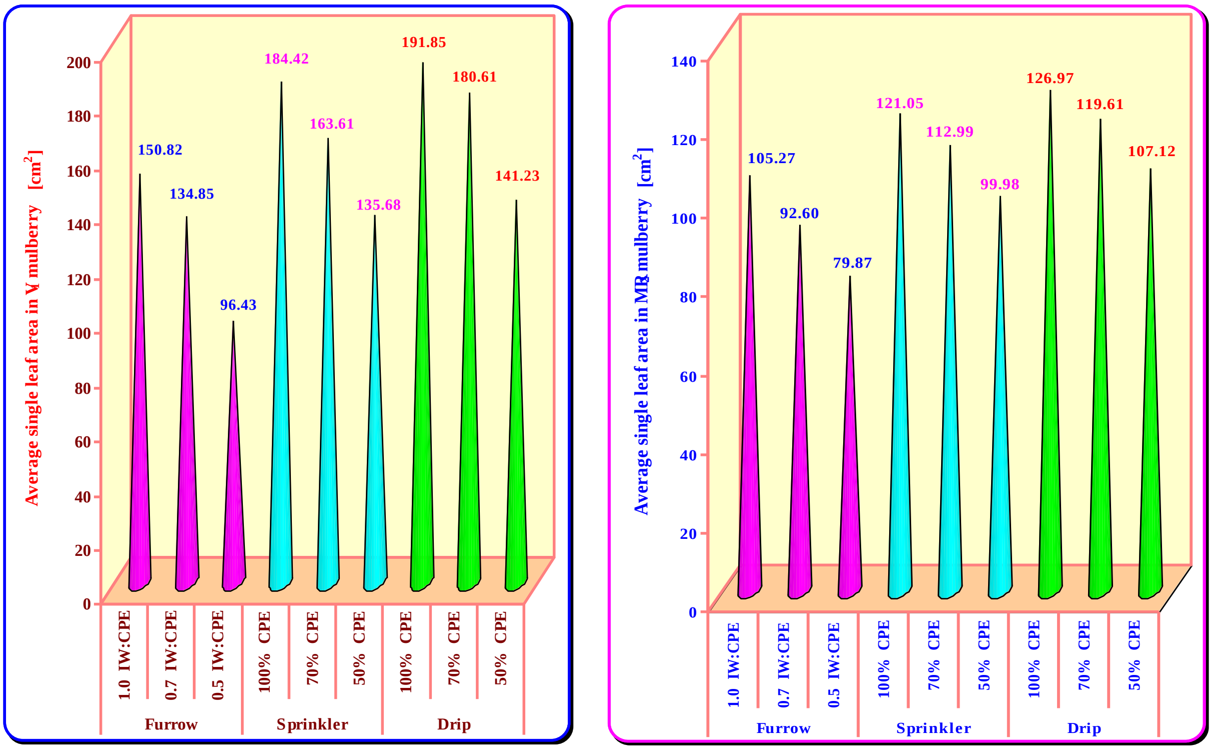


Fig. 4 Average leaf productivity under different system of water management in mulberry

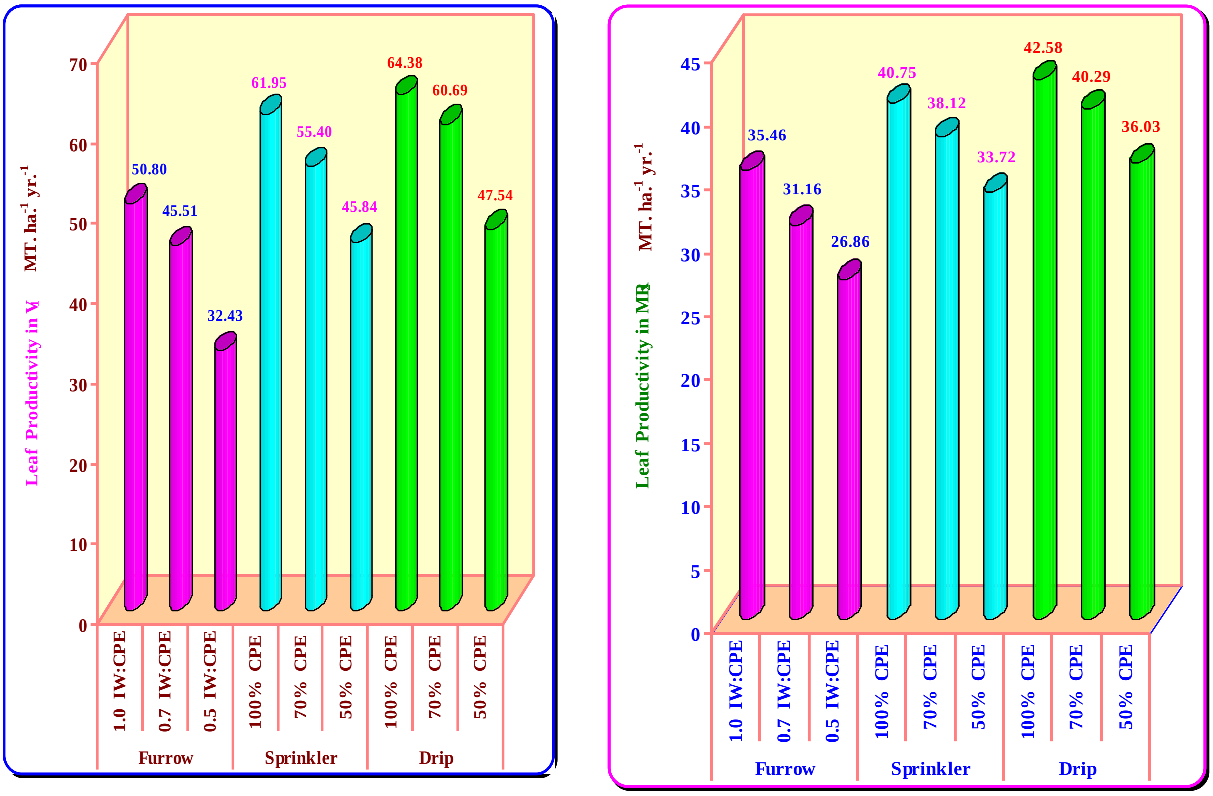


Fig. 5 WUE under farmers' practice, actual irrigation required & different system of water management in mulberry

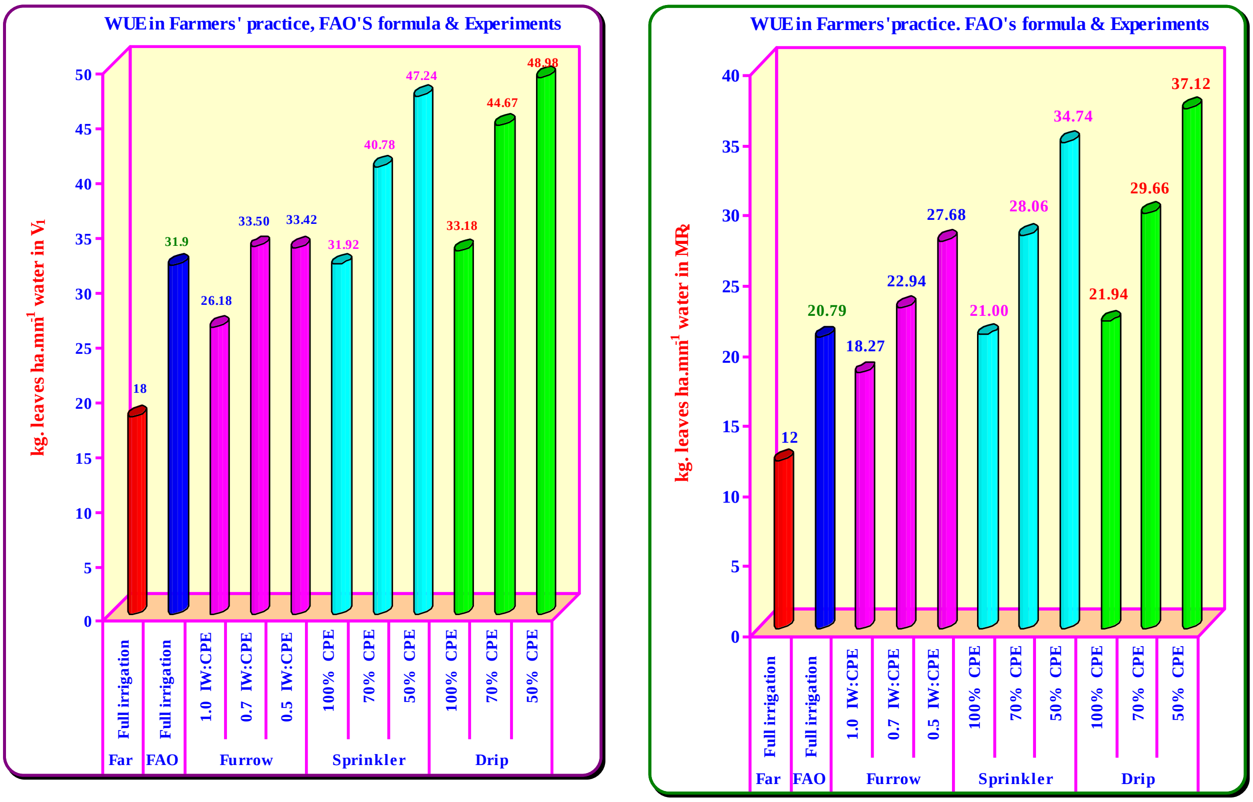
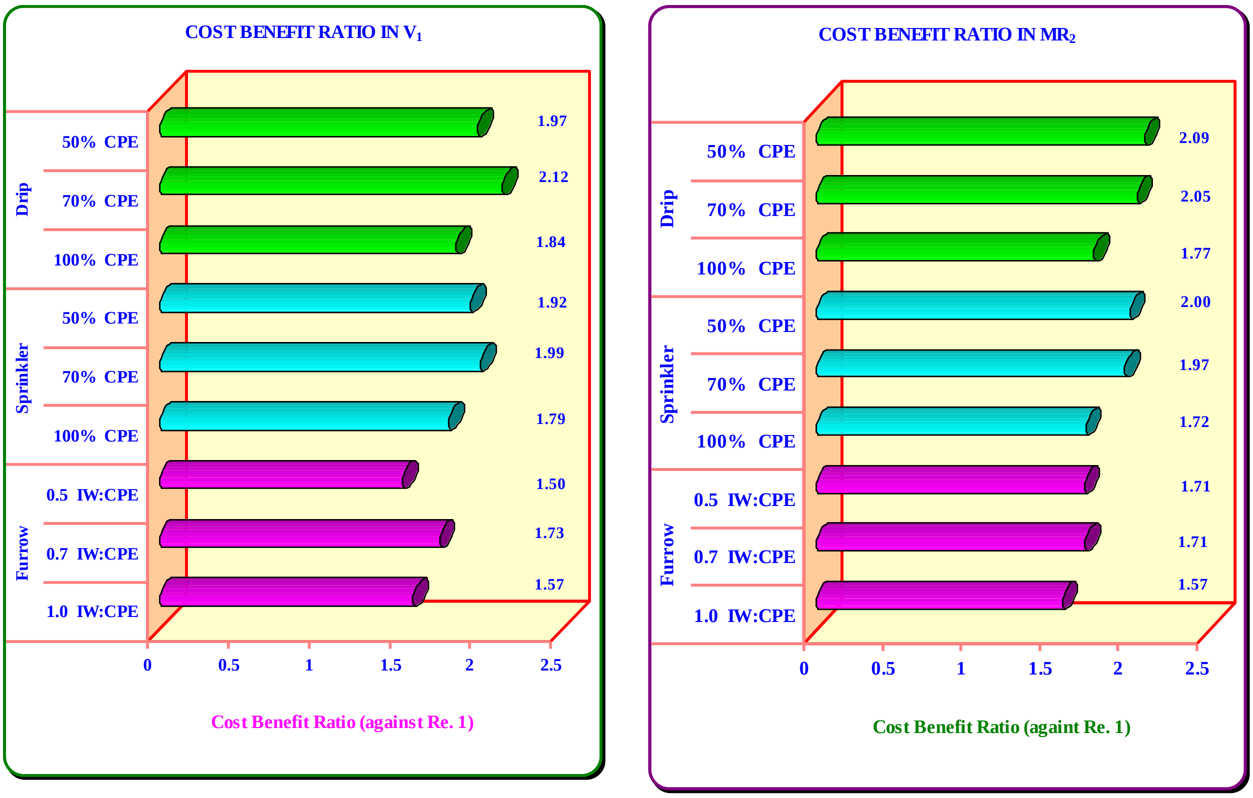
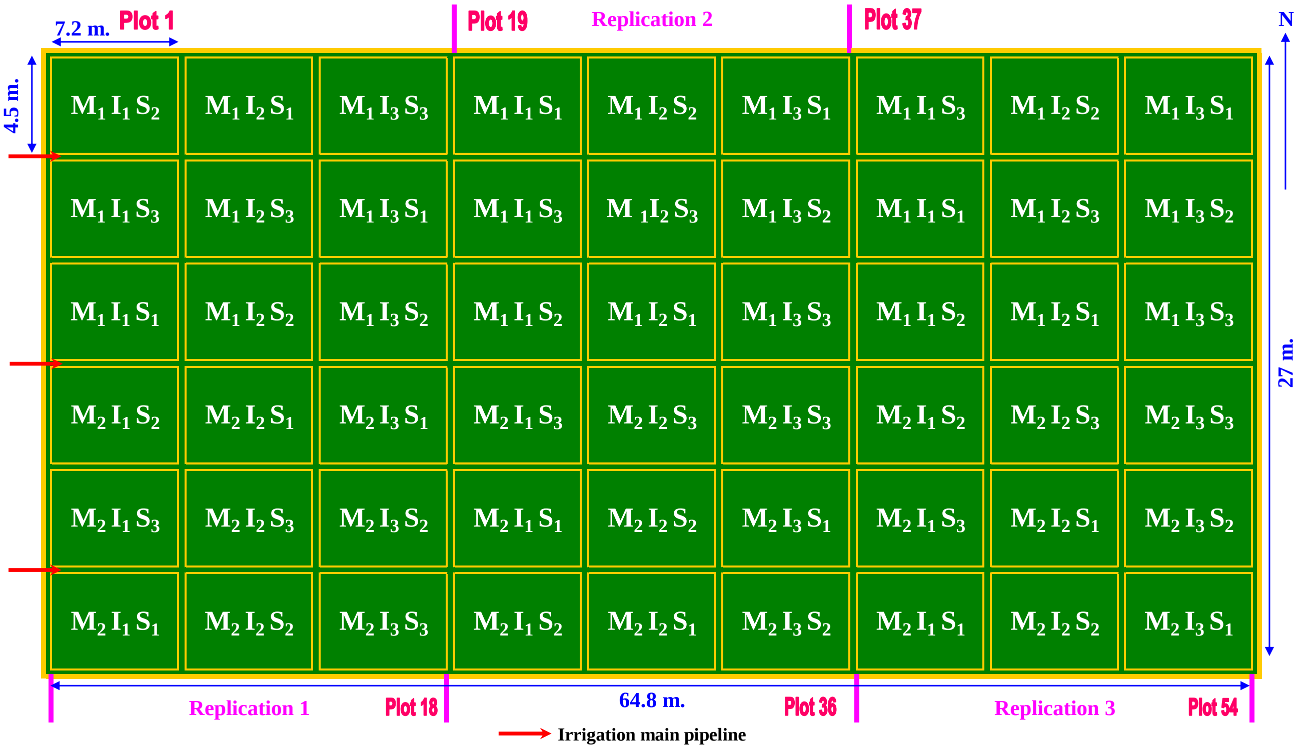


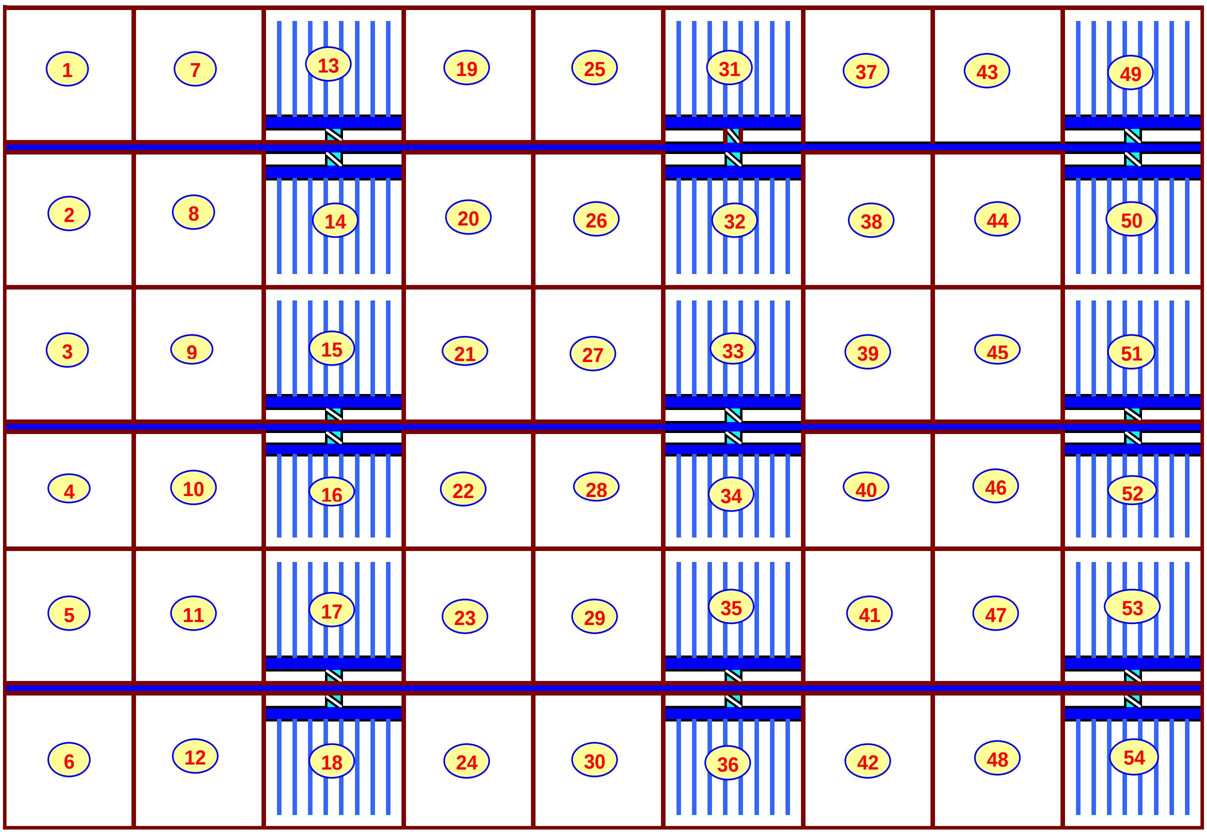
Fig. 6 Average cost benefit ratio under different system of water management in mulberry crop



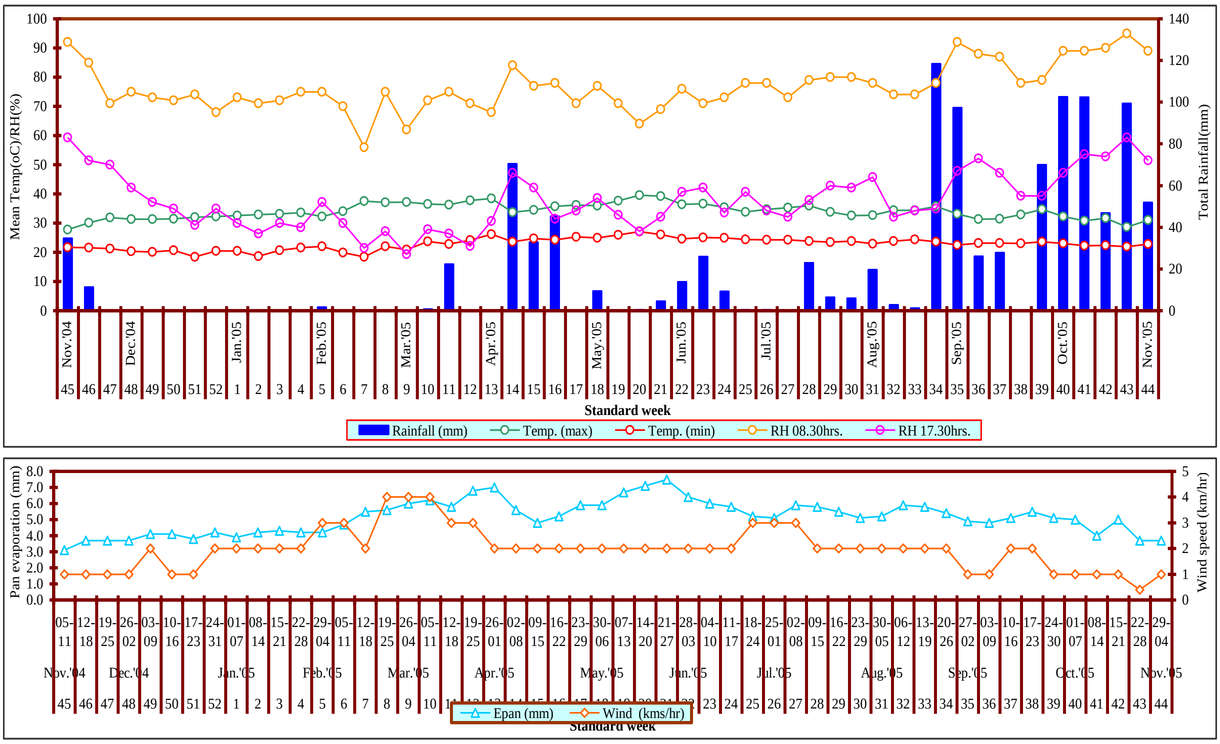
Annexure : 1 Layout of experiment field



Annexure : 2 Irrigation pipeline and experiment plot distribution

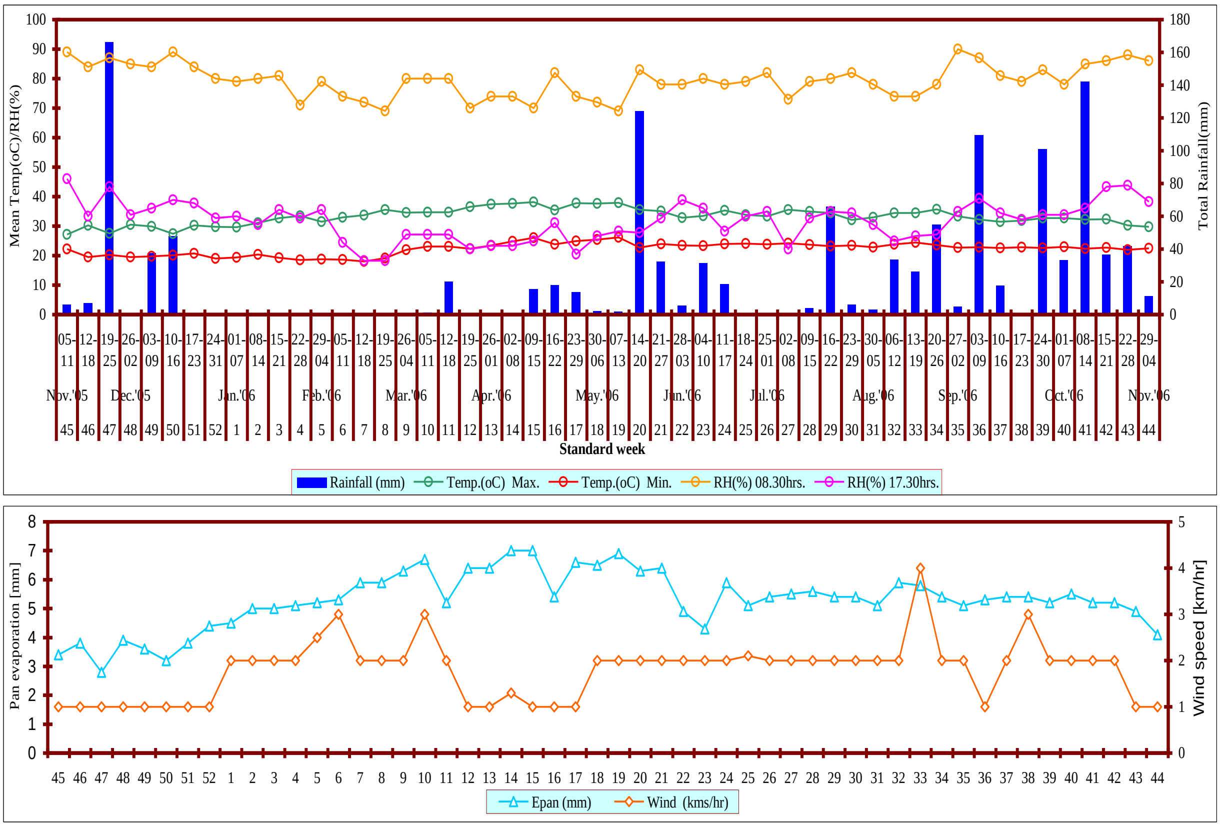


Annexure : 3 Meteorological data recorded during first year experimental period



Standard weeks: Crop 1 = 45 - 03; Crop 2 = 03 - 13 Crop 3 = 13 - 23; Crop 4 = 24 - 34

Annexure : 4 Meteorological data recorded during second year experimental period



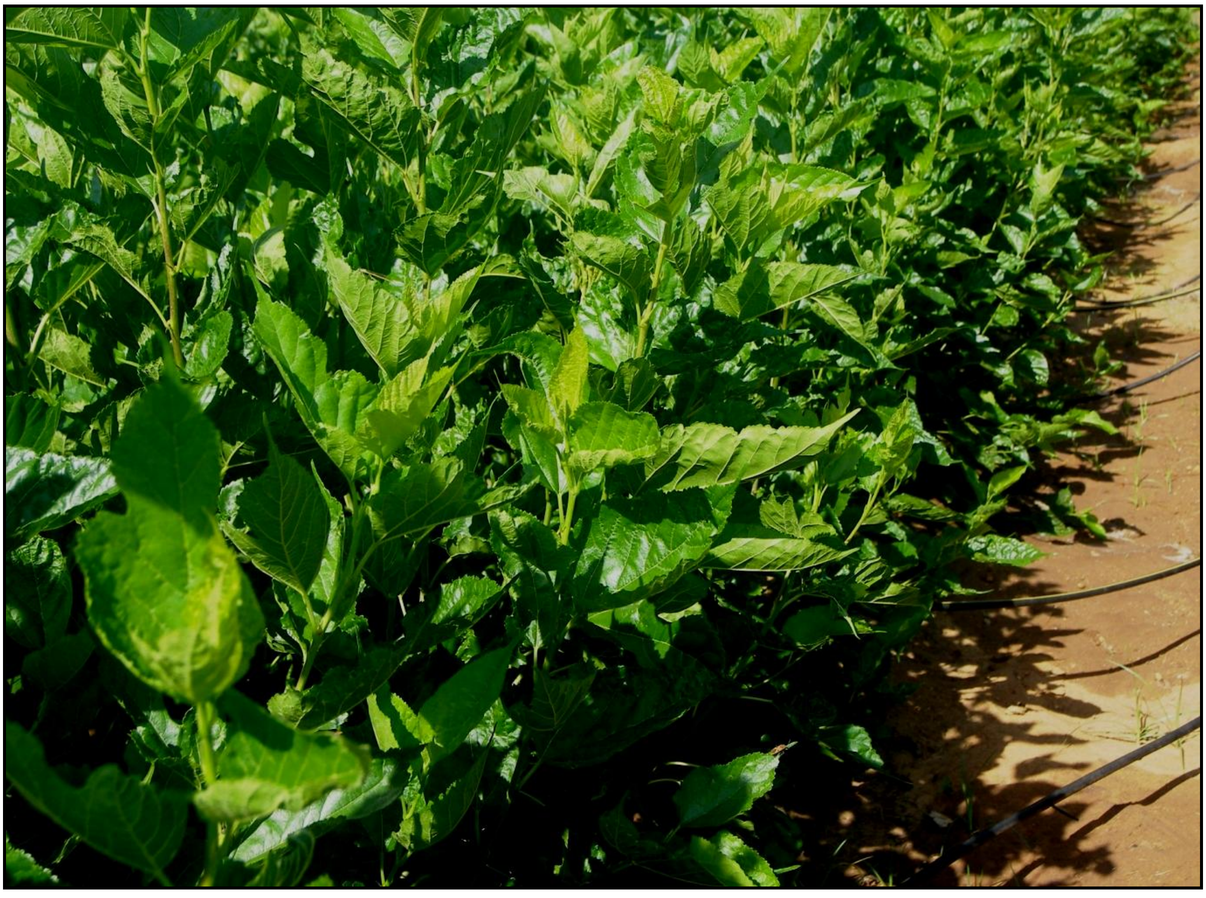
Standard weeks: Crop 1 = 48 - 06; Crop 2 = 06 - 16 Crop 3 = 16 - 26; Crop 4 = 26 - 36

Annexure : 5 Plate showing a view of portion of experiment mulberry plot under furrow irrigation

Annexure : 6 Plate showing a view of portion of experiment mulberry plot under furrow irrigation after pruning

Annexure : 7 Plate showing a view of portion of experiment mulberry plot (V1) under drip irrigation

Annexure : 8 Plate showing a view of portion of experiment mulberry plot (MR2) under drip irrigation



Annexure : 9 Plate showing a view of portion of experiment mulberry plot (V1) under micro-sprinkler irrigation (Top left corner insert a portion of MR2 & V1 plots**)**

Annexure : 10 Plate showing a view of portion of experiment mulberry plot (MR2) under micro-sprinkler irrigation

Annexure : 11 Plate showing a portion of experimental silkworm rearing

Annexure : 12 Plates showing a portion of experimental silkworm rearing

Annexure : 13 Plate showing silkworm ready for mounting for spinning

Annexure : 14 Plate showing cocoons in netrike after spinning

Annexure : 15 Plate showing cocoons after harvest

Annexure : 16 Plate showing cocoon reeled in Epprouvette

Annexure : 17 Plate showing weighment of raw silk filament