MATERIALS & METHODS

"Save water to save the world"
CHAPTER - III
MATERIALS AND METHODS

PART - I
STUDIES ON THE IMPACT OF DROUGHTS ON SERICULTURE IN TAMIL NADU [2001-'02 to 2003-'04] (SURVEY).

3.1. Materials:

Though the long-term average annual rainfall of India is 1160 mm, which is the highest anywhere in the world for a country of comparable size (Lal, 2001), the annual rainfall in our country however fluctuates widely. The highest rainfall in India of about 11,690 mm is recorded at Mousinram near Cherrapunji in Meghalaya in the northeast (Bose and Saxena, 2001). In this region rainfall as much as 1040 mm is recorded in a day. At the other extreme are places like Jaisalmer in Rajasthan in the west, which receives barely 150 mm of rain. Though the average rainfall is adequate, nearly three-quarters of the rain pours down in less than 120 days, from June to September. As much as 21% of the area of the country receives less than 750 mm of rain annually while 15% receives rainfall in excess of 1500 mm. Precipitation generally exceeds 1000 mm in areas to the east of Longitude 78°E. It reaches nearly to 2500 mm along almost the entire west coast and over most of Assam and sub-Himalayan West Bengal. Large areas of peninsular India receive rainfall less than 600 mm. Annual rainfalls of less than 500 mm is experienced in western Rajasthan and adjoining parts of Gujarat, Haryana and Punjab. Rainfall is equally low in the interior of the Deccan plateau, east of the Sahyadris. (Gupta and Deshpande 2004),

Per capita availability and utilizable water in our country is estimated as 1703.6 & 1022.7 m$^3$ respectively (as on 01.03.2005), its uneven distribution among states and seasons, for instance Meghalaya gets 9000 mm rainfall a year, drinking water shortage is severe during March to May. The annual per capita water uses in
Rajasthan during 1990s of about 562 m³ a level representing absolute scarcity. Massive shifting of irrigation from surface water source to ground water source from the level of around 33% during 1960’s to >50% in 3 decades reduced the ground water level and in many areas the static component of ground water is being tapped and the seawater intrusion into the aquifer is likely to become serious in coastal areas (Swaminathan, 1994).

Tamil Nadu state possesses 3.96% (1.30 crore ha) arable land and 6.08% (6.24 crores) population of the Nation with per capita arable land of 0.208 ha., which is 35% less against the national level area of 0.32 ha. Of the total geographical area 46.89 lakh ha. (36.0%) area was net sown and only 2.9% cultivable land left unutilized as waste land in the state (2003-04). The state receives average normal rainfalls of 961.9 mm. in four seasons in a year and agriculture is the main occupation in the state (Anonymous, 2004). Classification of land and distribution of average rainfall of Tamil Nadu are depicted in Fig. 3.1a & 3.1b respectively.

Severe droughts prevailed during 2001-'02 to 2003-'04 in southern states (Karnataka, Andhra Pradesh and Tamil Nadu) affected all agriculture activities including sericulture to a greater extent. The sericulture activities in Tamil Nadu have been affected very much by the droughts, mulberry area deeply declined and raw silk production of the state faced ever seen set back in the history of sericulture in the past 25 years (Rajaram et al., 2006). The over all impacts of droughts in southern states reflected on the raw silk production at the national level.

To asses the intricate impact of droughts during 2001-sericulture in the state of Tamil Nadu, Dharmapuri district identified for the study based on the major strength of seric 58.42% mulberry area and 71% cocoon and raw silk investigation included a case study in Pe'---
sericulture cluster in the Dharmapuri district and was mainly focused on the following aspects:

3.2. Methods:

3.2.1. Studies on rainfall during drought period in Dharmapuri district Vs. state level:

Season wise rainfall recorded at 29 rainfall stations in Dharmapuri district for previous 10 years of drought period were also collected for study the same with the drought period in the district and at the state level.

3.2.2. Case study in Palacode sericulture cluster in Dharmapuri district:

Palacode sericulture cluster in Dharmapuri district was selected for conducting a Case Study based on the right representative sericulture cluster in the district. In the Case Study number of sericulture villages, sericulture farmers, mulberry area, dfls uptake and cocoon production in the cluster before drought, during the drought and after the drought period and the status of sericulture farmers who have continued sericulture at the end of drought period in the cluster area etc., were covered. The impact of droughts on sericulture in the cluster area was aimed for comparison of the same with the district and the state level. [Copy of format designed and used for collection of information from sericulture farmers is given as Annexure 2].

3.2.3. Impact of drought on sericulture in Tamil Nadu Vs. National level:

The impact of drought in terms of decline in mulberry area, dfls uptake, cocoon and raw silk production in Tamil Nadu state to study similar set back if any in the past in the sericulture history of the state and recovery from the same etc., As the over all droughts prevailed in southern states reflected at the national level status of sericulture industry, a comparison on the same was also planned with the outcome of this study.
Classification of land area in Tamil Nadu (2003-04) Seanwise normal annual rainfall in Tamil Nadu state

- **Net area sown**: 37%
- **Forest**: 16%
- **Barren & uncultivable**: 4%
- **Other fallow**: 14%
- **Current fallow**: 7%
- **Misc. tree crops groves not under net area sown**: 2%
- **Permanent pastures and grazing**: 1%
- **Non agri. uses**: 16%

Classification of land and seasonwise normal rainfall in Tamil Nadu State

- **Winter**: 37.4 mm
- **Hot-Weather**: 128.4 mm
- **South-West**: 331.5 mm
- **North-East**: 464.6 mm
PART - II

STUDIES ON WATER STRESS MANAGEMENT IN MULBERRY.
(EXPERIMENTS)

Field experiments were conducted from November 2004 to October 2006 in demonstration mulberry farm of RSRS., Salem to study the water stress management in mulberry (*Morus* spp.) with relevance to silk production for sustainable sericulture under Tamil Nadu conditions.

3.3. Materials:

3.3.1. Experiment field location:

The demonstration mulberry farm of Regional Sericultural Research Station, Central Sericultural Research & Training Institute, Central Silk Board, Govt. of India and Centre for Advanced Studies in Botany & Sericulture, Salem, Tamil Nadu recognized by Periyar University, Salem is located at 11.39°N latitude & 78.10°E longitude and at an altitude of 278.28 m. above MSL.

3.3.2. Weather and climate:

The annual mean rainfall of Salem during the experimental period was 1164.5 mm received in 102 days. The mean annual maximum and minimum temperatures were 33.6 and 22.6°C respectively. The mean annual relative humidity recorded was 66.55 percent. The mean annual cumulative pan evaporation was 1901.2 mm and the mean velocity of wind was 1.9 kmph. Banerjee *et al.*, (1987) guidelines for collection and maintenance of meteorological data were followed during the entire period of experiments. Weather data during the experimental period is presented in Tables 3.1 and 3.2 and depicted in Fig.: 3.2 and 3.3.

3.3.3. Soil:

The growth and performance of mulberry is highly dependant on the nutritional status of the soil it grows on. Hence to know the soil characteristics and
## Weather Data Recorded During First Experimental Year (November 2004 - October 2005)

<table>
<thead>
<tr>
<th>Standard week</th>
<th>Month, Year Date</th>
<th>Temperature °C</th>
<th>Relative Humidity %</th>
<th>Evaporation (mm)</th>
<th>Wind speed (kms/hr)</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard week</td>
<td>Month, Year Date</td>
<td>Temperature °C</td>
<td>Relative Humidity %</td>
<td>Evaporation (mm)</td>
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WEATHER DATA RECORDED DURING SECOND EXPERIMENTAL YEAR (November 2005 - October 2006)

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WEATHER DATA RECORDED DURING FIRST EXPERIMENTAL YEAR (November 2004 - October 2005)

Standard weeks: Crop 1 = 45 - 03; Crop 2 = 03 - 13 Crop 3 = 13 - 23; Crop 4 = 24 - 34
WEATHER DATA RECORDED DURING SECOND EXPERIMENTAL YEAR (November 2005 - October 2006)

Standard weeks: Crop 1 = 48 - 06; Crop 2 = 06 - 16; Crop 3 = 16 - 26; Crop 4 = 26 - 36
fertility status for necessary corrections and improvements to maintain the soil health, soil testing is essential. As the soil type and pH which influence the growth of plants, vary from place to place and site to site, necessitate collection of adequate samples of soil to represent the entire field before planting of mulberry and periodical testing of soil once in 2 or 3 years depend upon the growth and yield performance of mulberry crop is suggested. As the mulberry garden selected for the study was established during 1999 and last soil testing of the garden was done during 2002, before commencement of the experiment testing of soil was planned. 6 soil samples each of 3 levels i.e., surface, 0-30 and 30-60 cm depth from V1 and MR2 plots and thus a total of 36 samples were collected as suggested by Prakash C.Bose (1988) and Mukund (1997).

The soil samples collected were air dried & passed through 2 mm sieve and analysed for mechanical textural characteristics and physical properties of soil following the method by Piper (1966) and chemical properties of soils like available Nitrogen (kg.ha\(^{-1}\)) [Subbiah and Asija, 1956]; available Phosphorus (kg.ha\(^{-1}\)) [Olsen et al., 1956]; available Potassium (kg.ha\(^{-1}\)) [Stanford and English, 1949]; Organic Carbon (%) [Walkley and Black 1934]; and Electrical Conductivity (EC) (dSm\(^{-1}\)) and pH of the soils as suggested by Jackson (1973). The soil analysis data of the experimental mulberry garden is presented in Table 3.3.

3.3.4. Crop and variety:

Selection of right mulberry variety suitable for agro climatic conditions of the area is very much essential for achievement of quality linked sustainable productivity. Two cultivated mulberry varieties namely V1 and MR2 suitable for Tamil Nadu and both established under 90x90cm spacing in an ideal conditions in the same garden in adjacent plots were selected for the study based on the improved high yielding variety (Sarkar et al., 1999) recommended by CSR&TI Mysore newly
introduced for popularization in the state of the former and ruling variety which occupies >65% of the total mulberry area in the state of the later.

3.3.5. Irrigation water:

The source of irrigation water used for the experiment was Bore well. The quality of irrigation water was analyzed for pH, EC, total alkalinity, Cl\textsubscript{2}, SO\textsubscript{4}, Ca, Mg, Na, K, RSC, SAR and TSS. Table 3.4 shows the quality of irrigation water.

3.3.6. Silkworm breed:

Selection of right silkworm breed suitable for different regions is very important in sericulture for crop sustainability and quality cocoon production. Based on the wide adaptability of PM x CSR\textsubscript{2} multi bivoltine Cross Breed silkworm for different regions and seasons in Tamil Nadu which replaced different breeds ruled for decades in the field of multi bivoltine sericulture in southern states of the country within a short period of time has been selected for the experiment (Rajaram and Jayanth Jayaswal, 2004).

3.3.7. Silkworm rearing house:

Next to mulberry leaf quality, silkworm rearing climate plays a major role with a share of 37.8% for success of cocoon crop (Miyashitha, 1986) and hence an ideal rearing house is one of the most important requirements in sericulture. Studies proved that Open Rearing house Model [ORM] found to be ideal for all seasons throughout the year in regions with high temperature and low humidity like Tamil Nadu (Rajaram \textit{et al.}, 2007). More over rearing house adapted with IBTMM technology helps to maintain optimum temperature & humidity required for silkworm in an eco-friendly manner, which improves the quality and performance of silkworm cocoon crop (Rajaram and Benchamin, 2003), and hence an ORM adapted with IBTMM technology was selected for conducting silkworm rearing throughout experimental period.
Table 3.3

Soil characteristics of the experimental field:

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<th>Sl.No.</th>
<th>Particulars</th>
<th>Composition</th>
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<tr>
<td>I</td>
<td>Mechanical properties (Soil Texture) (Piper, 1966)</td>
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<tr>
<td></td>
<td>i Coarse sand (%)</td>
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</tr>
<tr>
<td></td>
<td>ii Fine sand (%)</td>
<td>30.06</td>
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<td></td>
<td>iii Silt (%)</td>
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<td>iv Clay (%)</td>
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<td></td>
<td>v Textural class</td>
<td>Sandy clay loam</td>
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<tr>
<td>II</td>
<td>Physical properties (Piper, 1966)</td>
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</tr>
<tr>
<td></td>
<td>i Bulk density (g/cm$^3$)</td>
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<tr>
<td></td>
<td>ii Field capacity (%)</td>
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<td></td>
<td>iii Wilting point (%)</td>
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<td>III</td>
<td>Chemical properties</td>
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<td></td>
<td>i Available N (kg ha$^{-1}$) (Subbiah and Asija, 1956)</td>
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<td>ii Available P (kg ha$^{-1}$) (Olsen et al., 1954)</td>
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<td></td>
<td>iii Available K (kg ha$^{-1}$) (Stanford and English, 1949)</td>
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<td>iv Organic carbon (%)</td>
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<td>v EC (dSm$^{-1}$) (1:2 soil water solution) (Jackson, 1973)</td>
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<td>vi pH (1:2 soil water solution) (Jackson, 1973)</td>
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Table 3.4

Quality of irrigation water:

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<td>Total alkalinity (meq/l)</td>
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<td>Cl$_2$ (meq/l)</td>
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<td>11</td>
<td>SAR</td>
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<td>12</td>
<td>Total soluble salts (ppm)</td>
<td>2181.4</td>
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</table>
3.4. Methods:

3.4.1. Experiment plan layout:

Two cultivated mulberry varieties namely $V_1$ and $MR_2$ in Tamil Nadu with 90cm x 90cm plant spacing in main plots under ideal conditions in adjacent plots in the same garden established in the year 1999. Three types of irrigation selected for the study include furrow irrigation (popular irrigation method followed in the state), sprinkler & drip method of irrigations (advanced modern methods of irrigation under micro-irrigation) in sub plots and three levels of irrigation in sub-sub plots followed in the experiments were 1.0; 0.7 & 0.5 IW:CPE in furrow and 100; 70 & 50% of CPE value of Class A open Pan Evaporimeter in micro-irrigation methods.

Thus 18 treatment combinations with all three factors of the experiments in each replication and for 3 replications a grand total of 54 sub-sub plots with border row around each plot to avoid different irrigation level effect in Split-Split Plot Design (SSPD) as suggested by Sukhatme and Amble (1985) was designed for the experiments. Each plot size with gross area of 56.7 m$^2$ (6.3mx9m) with 7 rows of 10 plants and a net area of 32.4 m$^2$ (4.5m x 7.2m) with 5 rows of 8 plants and thus a total of 40 plants maintained per plot for each treatment as recommended by Chaturvedi and Sarkar (2000) for research purposes in mulberry. Irrigation water requirement for mulberry crop equal to the value of CPE of Class A open Pan Evaporimeter at 50% ASM recommended by Naoi (1975, 1977) has been followed in the experiment. The experiment field lay out depicted in Fig. 3.4.

3.4.2. Treatments:

The design of the experiment selected was Split Split Plot Design [SSPD]. The experimental plot layout as mentioned above in 3.4.1., a total mulberry area of 31 m$^2$ in adjacent plots were considered as two main plots of the rent and the variety was given symbol $M_1$ and $M_2$ respectively.
Each main plot was divided into 9 sub plots to accommodate 3 methods of irrigation namely Furrow, Sprinkler & Drip and were given symbol I₁, I₂ and I₃ respectively in 3 replications. Each sub plot was divided into 3 sub-sub plots to accommodate 3 levels of irrigation i.e., Upper, middle & lower levels and given symbol S₁, S₂, S₃ respectively. Thus all 18 treatments in each replication, for 3 replications a total of 54 sub-sub plots as suggested by Sukhatme and Amble (1985) with treatment combination of three factors given symbol M₁I₁S₁; M₁I₁S₂; M₁I₁S₃ & so on... upto M₂I₃S₃ in Split Split Plot Design [SSPD] as in fig. 3.4 was prepared for the experiment. Treatment details of experiments are presented in Table 3.5

3.4.3. Preparation for furrow irrigation:

Formed ridges along the row of mulberry plants and furrows in between two rows with soil and maintained the same throughout the crop to facilitate application of irrigation water in furrows in all plots designated for furrow irrigation treatments. Water from irrigation source (Bore-well) pumped with 7.5 H.P. electric motor and conveyed upto the experiment plots through main PVC pipeline with 63mm OD. In upper level irrigation (S₁) treatment plots irrigation water applied in all furrows and in middle (S₂) & lower levels (S₃) irrigation treatment plots irrigation water applied in alternate furrows. Separate valve fixed for each plot for application of desired quantum of irrigation water as per the treatment requirements.

Physical measurement of water discharge at experiment plot apart from the discharge measurement per unit time with the help of water meter repeated done before commencement of the experiment in both years for standardization of timing for desired quantum of water application as per the treatment requirements. Plates 1 and 2 shows a portion of experiment plot under furrow irrigation.

3.4.4. Installation of sprinkler irrigation system:

For sprinkler irrigation, adequate number of Krishi micro-sprinklers (green) (2kg/cm²) at a height of 5.5' from ground level with supports of wooden poles and
<table>
<thead>
<tr>
<th>M₁I₁S₂</th>
<th>M₁I₂S₁</th>
<th>M₁I₃S₃</th>
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<th>M₁I₂S₂</th>
<th>M₁I₃S₁</th>
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Fig. 3.4
64.8 m.

Irrigation main pipeline

EXPERIMENT LAYOUT
(Split split plot design)
# Table 3.5

## Treatments' combinations of the experiments and distribution details

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<th>Replication 1</th>
<th><strong>Plot No.</strong></th>
<th><strong>Treatments</strong></th>
<th><strong>Symbol</strong></th>
<th><strong>Plot No.</strong></th>
<th><strong>Treatments</strong></th>
<th><strong>Symbol</strong></th>
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<td>V1 Furrow Irrigation 0.7 IW : CPE</td>
<td>M1 I S2</td>
<td>7</td>
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<td>M1 I S3</td>
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<td>M1 I S2</td>
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<td>54</td>
<td>MR2 Drip Irrigation 100% CPE</td>
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Plate 1. A view of portion of experiment mulberry plot under furrow irrigation

Plate 2. A view of portion of experiment mulberry plot under furrow irrigation after pruning
wooden bar frames were installed in plots designated for sprinkler irrigation treatments. The micro-sprinklers were fixed in 20 mm (OD) ISI quality PVC pipe with necessary accessories made of PVC all and the set up was fixed on the wooden frame permanently throughout the experiment period. Irrigation water from the source (Bore well) pumped with 7.5 H.P. electric motor and conveyed to the experiment field through 63 mm (OD) main PVC pipeline upto sub-sub plot and was linked by 34 mm OD PVC pipe to the micro-sprinkler fixed pipe for uniform discharge of irrigation water. Separate valve fixed for individual plot for application of desired quantum of irrigation water as per the treatment requirements.

Operation of the system repeatedly checked before commencement of the experiment in both years by physical measurement of water spray from sprinkler in individual plot apart from the measurement of water discharge per unit time from the discharge pipe with help of water meter for standardization of timing for desired quantum of irrigation water application as per the treatment requirements. Plates 3 & 4 shows a portion of experiment plots under micro-sprinkler irrigation.

3.4.5. Installation of drip irrigation system:

Irrigation water from the source (Bore well) pumped with 7.5 H.P. electric motor and conveyed through 63 mm (OD) main pipe line upto experiment field sub plots. From the main pipe line a parallel sub pipe line was drawn to install drip system with an ISI quality 12 mm laterals one line for each row of mulberry plants in the plots designated for drip irrigation treatments. For individual plant @ one dripper (4lph) were fixed in the laterals. Separate valve for each plot fixed in the outlet of main pipe connecting the parallel sub-line for desired quantum of irrigation water application as per the treatment requirements. Pressure head of 1.2 KSC was maintained throughout the experiment period for uniform supply of irrigation water by drippers for individual plants. Irrigation pipe line & distribution of plots depicted in Fig. 3.5
Plate 5. A view of portion of experiment mulberry plot (MR2) under drip irrigation

Plate 6. A view of portion of experiment mulberry plot (V1) under drip irrigation
Irrigation pipeline and experiment plot distribution
Operation of the system repeatedly checked before commencement of the experiment in both years by physical measurement of water discharge from dripper in individual plot apart from the measurement of water discharge per unit time from the discharge pipe with help of water meter for standardization of timing for desired quantum of water application as per the treatment requirement. Plates 5 & 6 shows a portion of experiment plots under drip irrigation.

3.4.6. Irrigation schedule:

3.4.6.1. Surface irrigation:

In upper level irrigation (S₁) application of irrigation water equal to 1.0 IW:CPE in all furrows, in middle (S₂) & lower levels (S₃) irrigation water equal to 0.7 & 0.5 IW:CPE value of Class A open Pan Evaporimeter respectively in alternate furrows after deducting the effective rainfall recorded if any during the schedule were applied. Irrigation water equal to CPE value of Class A open Pan Evaporimeter at 50% ASM as recommended by Naoi, 1975 and 1977 for mulberry and irrigation scheduled at 50% depletion of soil moisture were followed in the experiments.

3.4.6.2. Micro irrigation (Sprinkler and Drip):

In upper level irrigation (S₁) application of irrigation water equal to 100% CPE value and in middle (S₂) & lower level (S₃) irrigation water equal to 70 & 50% CPE value of Class A open Pan Evaporimeter respectively once in alternate days after deducting the effective rainfall recorded if any during the schedule were applied under micro irrigation methods.

Quanta of irrigation water used crop wise under different methods and levels of irrigation in the experiments during experimental period are given in Appendix I.
Plate 3 A view of portion of experiment mulberry plot (V1) under microsprinkler irrigation (Top left corner both MR2 & V1 plots)

Plate 4 A view of portion of experiment mulberry plot (MR2) under microsprinkler irrigation
3.4.7. Maintenance of mulberry garden and conduct of experiments:

Package of practices for maintenance of mulberry garden under irrigated conditions as per the recommendations of the CSR&TI., Mysore (Krishnawami, 1978; Dandin et al., 2005) were followed for maintenance of the experiment garden.

Required weather data were collected from the Salem Observatory Station, Meteorology (Agri.) department, Government of India, Salem on daily basis throughout experimental period. Effective rainfall for the actual rainfall received if any during irrigation schedule was calculated using USDA SCS formula on daily basis for adjustment of the same from quantum of irrigation water applied and soil moisture depletion on daily basis were arrived from meteorological data input in FAO’s Cropwat-8 software. To study the soil moisture distribution pattern under different methods of irrigation, soil samples collected with help of screw auger at 0-15; 15-30; 30-45 cm depths after 1st, 2nd, 3rd, 4th, 5th, 6th and 7th day of irrigation (for one week) in furrow irrigation plots and in drip & sprinkler irrigation plots after 24 hours of irrigation were determined by oven dry method (USDA, 1970).

3.4.8. Silkworm rearing:

PM x CSR2 Cross Breed silkworm reared in mass with utmost care during chawki stage as recommended by Krishnaswami (1986), after third moult @ 200 worms per replication for 18 treatments and 3 replications, a total of 54 partitions of 2’x2’ size made on rack and reared on feeding ad-libitum quantity of mulberry leaves of respective treatments till spinning separately following the technologies developed and recommended by the CSR&TI., Mysore (Krishnawami (1970); Benchamin and Nagaraj (1987); and Dandin et al., (2005). On fifth day all cocoons were harvested replication wise separately and assessed the quality of the same including reeling parameters. Plates 7 & 8 shows the outer & inner view of rearing house; Plates 9, 9a; 10; 11&12 shows a portion of experiment rearing of silkworm, riped worms for mounting for spinning cocoons, silkworms mounted on netrika for spinning cocoons, cocoons in netrika and harvested cocoons.
4 crops per annum (5th crop during peak rainy season due to availability of irrigation water above treatments level to plants experiments were not conducted) and thus a total of 8 experiments crops were taken in two years experimental period and the following parameters were studied.

3.4.9. Mulberry growth observation:

3.4.9.1. Branch height:

Branch height of randomly selected 6 plants in each treatment were measured, averaged and expressed in cm. in every crop and the mean branch height of 8 crops from two experimental years under each treatment were recorded for analysis.

3.4.9.2. Plant height:

Plant height was measured from the bottom of the stem of randomly selected 6 plants under each treatment, averaged and expressed in cm. in every crop and the mean plan height of 8 crops from two experimental years under each treatment were recorded for analysis. Plates 13 & 14 shows the height of mulberry plants under different levels of irrigation treatments.

3.4.9.3. Number of branches per plant:

Number of branches of randomly selected 6 plants under each treatment were counted, averaged and expressed as number of branches, in every crop and the mean numbers of branches per plant of 8 crops from two experimental years under each treatment were recorded for analysis.

3.4.9.4. Total shoots length per plant:

Total shoots length of randomly selected 6 plants in each treatment were measured, averaged and expressed in cm. in every crop and the mean total shoots length per plant of 8 crops from two experimental years under each treatment were recorded for analysis.
Plate 7. Outer view of silkworm rearing house

Plate 8. Inner view of silkworm rearing house
3.4.9.5. **Number of leaves per branch:**

Total number of leaves per branch of randomly selected 6 plants in each treatment were measured, averaged and expressed in numbers and the mean numbers of leaves per branch of 8 crops from two experimental years under each treatment were recorded for analysis.

3.4.9.6. **Leaf area:**

Leaf area of leaf below 5th position from top of randomly selected 6 plants in each treatment were measured in Laser meter, CI-203 USA make, averaged and expressed in cm². Random sample verification of the leaf area measured in Laser meter were made by disc method in each crop. The mean leaf areas of 8 crops from two experimental years under each treatment were recorded for analysis.

3.4.9.7. **Leaf area index (LAI):**

To find Leaf Area Index, number of branches per plant, number of leaves per branch, leaf area of individual leaf were noted. The LAI was calculated by using the following formula and the mean leaf area of 8 crops from two experimental years under each treatment were recorded for analysis.

\[
\text{LAI} = \left( \frac{\text{(No. of branches/plant) x (No. of leaves/branch) x (Leaf area of individual leaf)}}{\text{Plant spacing}} \right)
\]

3.4.9.8. **Leaf yield per plant:**

Entire leaves from randomly selected six plants in each treatment were harvested, weighed and averaged in each crop and the mean leaf weight per plant of 8 crops from two experimental years under each treatment to arrive mean leaf yield plant⁻¹ crop⁻¹ and converted for 5 crops to obtain leaf yield in gm. plant⁻¹year⁻¹ in each treatment and recorded for analysis (Sreenivasa Shetty *et al.*, 1990).

3.4.9.9. **Leaf yield per ha:**

Leaf harvest during silkworm rearing were weighed every time plot wise, stored for feeding silkworms. On completion of the crop left over leaves in the plot harvested and computed with leaves already harvested and calculated the leaf yield
Plate 13. 1st row with 0.7 & 4th row with 1.0 IW:CPE level under furrow irrigation in V1; middle 2 rows are border row for each treatment.

Plate 14. 1st row with 70 & 4th row with 100% CPE level under drip irrigation in V1; middle 2 rows are border row for each treatment.
yield crop⁻¹ ha⁻¹. Thus from the mean leaf yields of 8 crops of two experimental years under each treatment were arrived the leaf yield crop⁻¹ ha⁻¹ and the same was computed for 5 crops to obtain the leaf yield in kg. ha⁻¹ year⁻¹ (Sreenivasa Shetty et al., 1990) and recorded for analysis.

3.4.9.10. Water Use Efficiency (WUE) :

WUE in terms of quantity of leaves produced in kg. per ha.cm irrigation water applied under each treatment in every crop and thus the mean WUE of 8 crops from 2 years experimental period were recorded under each treatment for analysis.

3.4.10. Mulberry leaf quality analysis :

3.4.10.1. Leaf Moisture Content (LMC) :

50 leaves between 5th to 9th position from the top were randomly collected from 10 different branches at 8.30 a.m. from each treatment plot in each crop, after recording the initial weight, the leaves were allowed to release moisture at room temperature for 48 hours and then dried in an oven at 80°C for 48 hours and the LMC were calculated using the following formula: (Vijayan et al., (1996)

\[
\text{LMC} \% = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Fresh weight}} \times 100
\]

Thus the mean LMC of 8 crops from two years experimental period were recorded under each treatment for analysis.

3.4.10.2. Moisture Retention Capacity (MRC) :

50 leaves between 5th to 9th position from the top were randomly collected from 10 different branches at 8.30 a.m. from each treatment plot in each crop, after recording the initial weight, the leaves were allowed to release moisture at room temperature at 6th hr. weight of leaves were recorded again and then at 48th hr. were dried in an oven at 80°C for 48 hrs. and the MRC in % after 6 hours of harvest were calculated using the following formula: (Vijayan et al., (1996)

\[
\text{MRC} \% = \frac{\text{Weight after 6hrs} - \text{Oven dry weight}}{\text{Fresh weight} - \text{Oven dry weight}} \times 100
\]
Thus the mean MRC % of 8 crops from two years experimental period were recorded under each treatment for analysis.

3.4.11. Mulberry leaf quality analysis:

3.4.11.1. Protein content of leaf:

Soluble protein was extracted from mulberry leaves collected from each treatment plot in each crop following the method described by Mahadevan and Sridhar (1986). This extract was used to estimate the total soluble protein following Lowry’s method (Lowry \textit{et al.}, 1951) Thus the mean protein content of 8 crops from two years experimental period were recorded under each treatment for analysis.

3.4.11.2. Total Sugar content in leaf:

Soluble sugars were extracted from mulberry leaves collected from each treatment plot in each crop following the method described by Mahadevan and Sridhar (1986). This extract was used to estimate the total soluble sugars following the phenol sulphuric acid method (Dubois \textit{et al.}, 1956) Thus the mean total soluble sugar content of 8 crops from two years experimental period were recorded under each treatment for analysis.

3.4.12. Silkworm growth observation:

3.4.12.1. Silkworm crop schedule Larval feeding & moulting duration:

Silkworm rearing @ 4 experimental crops per annum and thus 8 crops from two years experimental period were conducted following the rearing technologies recommended by Krishnawami (1970); Benchamin and Nagar (1987); and Dandin \textit{et al.}, (2005). The silkworms were reared on ad libitum quantity of leaves till spinning. The growth of silkworms, feeding and moulting behavior under each treatment was recorded for crop performance analysis.

3.4.12.2. Larval weight:

Growth of silkworm larvae and average weight of mature larvae under each treatment were observed and recorded in all 8 crops conducted during the
experimental period for overall analysis of the growth and performance under different treatments.

3.4.13. **Silkworm rearing crop performance:**

3.4.13.1. **Cocoon yield by number / 10000 larvae reared:**

Cocoon yield obtained from 200 larvae reared under each treatment in 3 replications were counted and converted for 10000 larvae in all 8 crops during the experimental period of two years and recorded the mean cocoon yield by numbers under different treatments for analysis of the same.

3.4.13.2. **Cocoon yield by weight / 10000 larvae reared:**

Cocoon yield obtained from 200 larvae reared under each treatment in 3 replications were weighed and converted for 10000 larvae in all 8 crops during the experimental period of two years and recorded the mean cocoon yield by weight in kg. under different treatments for analysis of the same.

3.4.14. **Cocoon analysis:**

3.4.14.1. **Single cocoon weight:**

After harvest of cocoons randomly selected 25 numbers of cocoons from each treatment in all 8 crops were weighed, averaged to arrive single cocoon weight in g. and mean single cocoon weight of 8 crops in 2 years experiment was recorded treatment wise for study and analysis.

3.4.14.2. **Single cocoon shell weight:**

The cocoons selected for assessment single cocoon weight were cut opened, after removal of pupa and larval skin the shell weight of the corresponding cocoon were recorded in each treatment and thus the mean single shell weight of 8 crops were recorded treatment wise for study and analysis.

3.4.14.3. **Single cocoon shell ratio:**

From single shell and cocoon weight, the single shell ratio (SR%) were calculated in each treatment in all 8 crops replication wise and the mean SR% for each treatment were recorded for analysis of the same.
3.4.15. Cocoon reeling parameters:

Reeling characters of silk cocoons were tested by single cocoon reeling in hand operated simple machine “Epprouvette” a wrap reel having 1.125 metres periphery swift with an indicator used for single cocoon test reeling. Single cocoon reeling of 10 cocoons / replication in all 8 crops were done with the help of Demonstration Cum Technical Service Centre (DCTSC), Central Silk Technological Research Institute, (CSTRI), Central Silk Board, at Dharmapuri. The following data were collected.

3.4.15.1. Single cocoon filament length:

Single cocoon reeling of 10 cocoons from each replication and thus 30 cocoons from each treatment in all 8 crops were done and the average single cocoon filament length in metre was calculated by using the following formula:

\[
\text{Average number of rotation of epprouvette } \times 1.125
\]

Mean single cocoon filament length in each treatment of 8 crops from two years experimental period were calculated and recorded for analysis.

3.4.15.2. Reeling break percent:

Average single cocoon reeling break is used to find out non breakable filament length (m) / cocoon, which is calculated by using the following formula:

\[
\text{Average non breakable} = \frac{\text{Total length of filament}}{\text{No. of cocoons + No. of breakage}}
\]

Mean reeling break percent of single cocoon in each treatment of 8 crops from two years experimental period were calculated and recorded for analysis.

3.4.15.3. Raw Silk Recovery percent (RSR%):

Raw silk recovery % is the ratio of amount of silk recovered from a unit amount of silk present in the cocoon i.e., the ratio between the quantum of silk obtained from single cocoon with that of its shell weight and expressed in percent.
Thus the mean RSR % of 8 crops of two years experimental period were recorded for each treatments for analysis of the same.

3.4.15.4. Single cocoon Denier:

Denier [D] is weight in g. of 9000 m. length of silk yarn. The term denier is used in silk industry to denote thickness of yarn. Single cocoon denier is the weight of silk yarn obtained from single cocoon divided by length of filament multiplied by 9000 m. Single denier is calculated by using the following formula.

\[
\text{Single cocoon denier} = \frac{\text{Weight of filament (g)}}{\text{Average filament length}} \times 9000
\]

Thus the mean single cocoon mean deniers of 8 crops of two years experimental period were recorded for each treatment for analysis of the same.

3.4.15.5. Renditta:

Renditta is quantity of cocoons required to produce one kg silk. Average renditta [R] single denier is calculated by using the following formula.

\[
\text{Single cocoon denier} = \frac{\text{Weight of cocoon used for reeling}}{\text{Weight of raw silk produced}}
\]

Thus the mean renditta of 8 crops of two years experimental period was recorded for each treatment for analysis of the same.

3.4.16. Water stress management & irrigation water savings:

Water stress management in mulberry varieties V1 and MR2 selected for the studies under different irrigation system, methods and irrigation managements adapted through various treatment combinations of the experiments to find out the minimum irrigation water requirements for these varieties without affecting the potential yield and compromise on the qualities of leaf for sustainable sericulture under Tamil Nadu conditions aimed as one of the major outcome of these studies.

In addition to the above it was planned for estimation of irrigation water savings out of these studies when compared to the quantum of irrigation water use
farmers level in traditional practice of irrigation methods being followed in mulberry cultivation and actual requirement of irrigation water by mulberry crop based on the estimation of evapotranspiration of the crop as per the FAO’s modified Penman-Monteith formula with certain meteorological data input using ROPWAT 8.0" a Computer Software released by the FAO for agriculture search purposes in the world.

4.17. Cost benefit ratio:

Additional mulberry area coverage under irrigation with the irrigation water saved through these studies and additional productivity of mulberry leaves & cocoon production and benefit to farmers when adaptations of the recommendations of these studies are emphasized in the thesis.

4.18. Irrigation Calendar:

Based on the combination of outcome of these research studies and the actual irrigation water requirement of mulberry crop as per the FAO’s modified Penman-Monteith formula, preparation and presentation of an appropriate model "Irrigation Calendar" for mulberry crop for the use of sericulture farmers, tension workers and stakeholders in the field of sericulture in Tamil Nadu also come a part of this thesis.

4.19. Statistical analysis:

*All raw data collected replication wise in all treatments in the experiments were entered in computer and at last stage of calculation only rounded to either in 2 decimal or 3 decimal points suitably.*

*All data of experiments statistically analysed in “Agres Software” [version 3.01 data entry module for Acres statistical software version 7.01 “ANOVA” Package suitable for agriculture researchers developed by the Tamil Nadu Agriculture University (TNAU), Coimbatore.*

Limitations in single cocoon reeling and its interpretation for reeling qualities of cocoons for commercial scale were considered, as the limitations are applicable for all treatments and hence comparable.