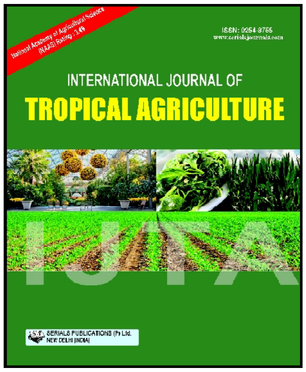


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# Irrigation Water Savings in Mulberry Cultivation without Affecting the Quality Linked Productivity of Raw Silk and Income to Sericulture Farmers

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***Abstract:*** Cultivation of mulberry is mainly for its leaves the sole food for the silkworm, *Bombyx mori* L. for commercial production of raw silk. 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. Under traditional open irrigation method 1.5-2.0 acre inch water per irrigation in 7-10 days interval depending upon the soil is recommended for mulberry. After introduction of shoot harvest system, huge biomass is removed in five crops per annum intensified the requirement of irrigation water and other inputs for quality linked sustainable leaf productivity. About 500 liters of water is utilized for every kg of mulberry leaves produced at farmers' level under traditional irrigation system with low efficiency of water used.

Keeping in view for optimum use and save irrigation water in mulberry cultivation an experiment was conducted for 5 years in mulberry garden selecting the both cultivated mulberry varieties i.e., $MR_2$ (popular) and $V_1$ (high yielding) in Tamil Nadu during 2004-'09 with 3 types and 3 levels of irrigation with Split Split Plot Design. Under furrow method irrigation water equal to 1.0; 0.7 & 0.5 IW CPE value scheduled @ 50% ASM; sprinkler and drip irrigation method water equal to 100, 70 & 50% CPE scheduled alternate day. Results of the experiments revealed that maximum of 61.2% and 32.7% water savings under micro irrigation (drip) against farmers practice and as per FAO's modified Penmann and Monteith formula based irrigation water requirements for mulberry crop respectively and increase of 300% WUE. Maximum cocoon yield of 19.80 kg obtained for 10,000 larvae reared under treatments $M_1I_2S3$, $M_2I_1S_3$ followed by

$M_2I_1S_2$ with 19.76 and 19.74 in treatment $M_1I_2S_2$ and 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 and all yield performance among all treatments in respect of variety, types and levels of irrigation (M x IS) all three factors combined together were statistically non-significant at CD<P 0.05 level. The CB ratio of 1:2.12 and 1:1.99 in V1 and MR2 mulberry garden respectively as against 1:1.57 under furrow irrigation method.

***Key words:*** Cost Benefit ratio, Cumulative Pan Evaporation, Mulberry, Micro-irrigation, Raw Silk Renditta, water saving.

## INTRODUCTION

India is the second largest silk producing country in the world with 30,263 t raw silk production (2016-'17) and is unique in producing all known four varieties of natural silk namely mulberry, tasar, eri and muga. Of the total mulberry silk of 21,203 t produced in the country about 70.1% is produced from the traditional sericulture states namely Karnataka, Andhra Pradesh, West Bengal, Tamil Nadu and Jammu & Kashmir (Anonymous, 2017)[5]. In India 2.21 lakh ha area is under mulberry cultivation and 8.51 million people get employment through sericulture. About 80% of mulberry garden is under irrigated condition which shows the importance of irrigation for the crop. In Tamil Nadu presently sericulture is practiced in 29 districts with 17,788 ha mulberry area by 23,873 farmers and 2.20 lakh people get employment (Anonymous, 2017 [8]. Scarcity of irrigation water, manifold increase in price of inputs and high labour wages collectively attributes increase in cost of production poses threat to agriculture, sericulture being labour intensive agro-based cottage industrial nature of activity, the problem aggravates further.

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 (Anonymous, 2016)[4] 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)[20]. India being an agrarian country, its economic growth largely depends on the development of agriculture and 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 all four seasons (Anonymous, 2016)[6]. Insufficient irrigation water availability for mulberry cultivation due to low rainfall or failure of monsoon or frequent droughts found to be the major limiting factor for the industry (Rajaram *et al.,* 2006)[22].

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[13]; Gupta and Deshpande, 2004)[12] 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; hence the irrigation demand for mulberry crop is not possible to meet by rainfall alone.

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)[29]. 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)[3]. In India, agriculture sector uses about 93% of water whereas industry and domestic & commercial sectors use 3 & 4% respectively (Rakesh kumar *et al.,* 2005)[23].

In the above context, to achieve maximum Water Use Efficiency (WUE) in mulberry cultivation without compromise on the quality linked productivity of leaf and raw silk, "More Crop & Income for Drop of Water" as policy of this study was carried out.

## MATERIALS & METHODS

The study was drawn on Split split plot design as suggested by Sukhatme and Amble (1985)[28] 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 S1, S2 & S3. Computation of irrigation water for mulberry crop (Naoi, 1975)[18]; 1977)[19] of irrigation water equal to 100; 70 and 50% cumulative $E_{pan}$ value [CPE] scheduled @ 50% soil moisture depletion (SMD) in furrow method; same levels in both sprinkler & drip irrigation and scheduled at alternate day. Thus a total of 18 treatments in 3 replications totaling 54 plots with plant population as suggested by Chaturvedi, and Sarkar, (2000)[10] were made. All other package of practices recommended for mulberry garden maintenance was followed as described by Dandin *et al.,* (2005)[11].

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' field for 3 years (2007-'09) in the same locality. 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 based on the crop coefficient approach using FAO's modified Penman-Monteith formula (Richard G. Allen *et al.,* 1998)[24] was estimated.

Though all growth and quality parameters studied in all crops, important parameters like leaf productivity, WUE and water savings without compromise on the quality linked productivity of cocoons, raw silk and income to sericulture farmers are covered in this paper.

## RESULTS AND DISCUSSIONS

**Leaf yield :** Miyashitha (1986)[17] categorized the various factors contributing successful silkworm cocoon crop as mulberry leaves 38.2, rearing climate 37.0, rearing technology 9.3, silkworm race 4.2, silkworm eggs 3.1 and other factors 8.2%. 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 recorded under drip and sprinkler irrigation respectively compared to the full irrigation

under furrow irrigation in $V_1$ mulberry and the production potential was not maintained when irrigation water reduced >30% of CPE value.

In case 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 (**Table 2 and Fig. 1**).

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 (MxIS) 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 reduced >30% of CPE value, the variety could not maintain its potential productivity under any methods of irrigation. Whereas wide adoptability to water stress conditions was 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 up to 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 value 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:CPE) 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 $M_2I_1S_3$.

Water savings under drip irrigation with increased productivity without affecting the quality of the product reported in many crops. Sivanappan *et al.*, (1974)[26] 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)[27] 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)[2] recommended 80% $E_{pan}$ value of irrigation under drip scheduled alternate day for optimum leaf production in K2 mulberry. Similarly Mishra *et al.,* (1996[15] and 1997)[16] reported 33% of water savings without affecting the yield under drip in K2 mulberry. Benchamin *et al.*, (1997)[9] 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)[14] reported 30% water savings under drip irrigation in mulberry without affecting the leaf yield over traditional irrigation.

**Water Use Efficiency (WUE) :** Maximum 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 was much below (>26% & >28% respectively) the potential level of 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. Treatments $M_1I_3S_2$ (44.68) $M_1I_2S_2$ (40.78) in $V_1$ mulberry were found to be economically viable as the productivity were above full irrigation (1.0 IW:CPE) under furrow irrigation $M_1I_1S_1$ (26.18).

In case of $MR_2$, the maximum WUE of 37.13 kg leaf yield ha.mmÈ[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. 2**).

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)[1] 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)[25] in sugarcane reported that automatically controlled drip saved water up to 56% and yield increased by up to 52% WUE increased by 2.5 to 3 fold over surface irrigation and mulch reduced water by further 16% than the conventional irrigation. Ananthakrishna *et al.,* (1995)[2] 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. Benchamin *et al*., (1997)[9] reported better WUE in mulberry under drip & sprinkler irrigation methods.

Palanisami (2010)[21] reported that if 10% of water savings in agriculture sector in our country will benefit 14 mha additionally.

**Irrigation 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 up to **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 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**).

**Cocoon yield (by No. & wt.) :** Maximum cocoon yield of 9720.83 & 19.80; 9716.67 & 19.80 under treatments $M_1I_2S_3$; $M_2I_1S_3$ followed by $M_2I_1S_2$; $M_1I_2S_2$ with 9718.75 & 19.76; 9716.67 & 19.74 by No. & kg respectively for 10000 larvae reared was recorded all at lower levels of irrigation. The yield performance among all treatments in respect of variety, types and levels of irrigation (MIS) all three factors combined together were statistically non-significant at CD<P 0.05 level (**Table 2**).

**Renditta :** Requirement of green cocoons (kg) to produce a kg raw silk is termed as 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

**Table 1**
**Irrigation water requirement in ha mm crop$^{-1}$ under different practices Vs. experiment**

| *Season* | *Farmers' Practice* | *@ FAO's modified Penman-Monteith formula* | *Experiment* | | |
|---|---|---|---|---|---|
| Level | Full | Full | 100 % | 70% | 50% |
| Nov. - Jan. | 500.0 | 225.8 | 306.4 | 214.5 | 153.2 |
| Jan. - Mar. | 500.0 | 288.5 | 412.2 | 288.5 | 206.1 |
| Mar. - June | 500.0 | 299.4 | 427.6 | 299.4 | 213.8 |
| June - Aug. | 500.0 | 284.4 | 406.2 | 284.4 | 203.1 |
| Average | 500.0 | 288.6 | 388.1 | 271.6 | 194.1 |
| Water savings against Farmers' practice (ha mm) | | | 111.9 | 228.4 | 305.9 |
| | | Irrigation water savings (%) | 22.4 | 45.7 | 61.2 |
| Water savings against FAO's mPM formula (ha mm) | | | -99.5 | 16.9 | 94.5 |
| | | Irrigation water savings (%) | -34.5 | 5.9 | 32.7 |

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, 2011)[7].

**Cost Benefit Ratio (C:B) :** Muraleedhara *et al.,* (1994) reported CB ratio of 1:1.64 under drip irrigation in K2 mulberry. Production increases due to water savings and additional area coverage with it, improved mulberry varieties / silkworm breed & advancement in technologies collectively attributed for the increased returns to farmers for every rupee invested to the level of 1:2.12 & 1:1.99 in V1 & MR2 mulberry varieties respectively was recorded (**Fig. 3**).

## CONCLUSIONS

From the results it is concluded that as the potential productivity of V1, mulberry variety is comparatively high and its sustainable productivity level could maintain under narrow water stress conditions, it is recommended for places of assured irrigation facility available. Whereas MR2 mulberry variety could maintain its sustainable productivity under wide range of water stress conditions, the variety is recommended for places of limited irrigation available.

Based on the high production potentiality of V1 and MR2 varieties under drip irrigation, the drip

**Table 2**
**Average WUE and yield performance recorded under different treatments**

| *Treatments* | *Leaf yield (kg) ha$^{-1}$ year$^{-1}$* | *WUE (kg/ha. mm)* | *Cocoon yield/ 10000 larvae No.* | *(kg)* | *Renditta* |
|---|---|---|---|---|---|
| $M_1 I_1 S_1$ | 50801.479 | 26.180 | 9722.92 | 18.883 | 7.39 |
| $M_1 I_1 S_2$ | 45513.010 | 33.509 | 9714.58 | 19.250 | 7.97 |
| $M_1 I_1 S_3$ | 32434.575 | 33.429 | 9718.75 | 19.070 | 8.47 |
| $M_1 I_2 S_1$ | 61938.879 | 31.919 | 9716.67 | 19.386 | 6.94 |
| $M_1 I_2 S_2$ | 55396.198 | 40.785 | 9716.67 | 19.740 | 7.36 |
| $M_1 I_2 S_3$ | 45844.313 | 47.250 | 9720.83 | 19.800 | 7.94 |
| $M_1 I_3 S_1$ | 64377.156 | 33.176 | 9718.75 | 19.723 | 6.78 |
| $M_1 I_3 S_2$ | 60687.688 | 44.681 | 9727.08 | 19.726 | 7.09 |
| $M_1 I_3 S_3$ | 47537.233 | 48.995 | 9722.92 | 19.661 | 7.85 |
| $M_2 I_1 S_1$ | 35456.858 | 18.272 | 9718.75 | 19.440 | 6.90 |
| $M_2 I_1 S_2$ | 31159.854 | 22.941 | 9718.75 | 19.757 | 7.71 |
| $M_2 I_1 S_3$ | 26863.242 | 27.687 | 9716.67 | 19.804 | 7.79 |
| $M_2 I_2 S_1$ | 40746.583 | 20.998 | 9722.92 | 19.292 | 6.80 |
| $M_2 I_2 S_2$ | 38123.067 | 28.068 | 9725.00 | 19.641 | 7.18 |
| $M_2 I_2 S_3$ | 33719.615 | 34.754 | 9716.67 | 19.627 | 7.47 |
| $M_2 I_3 S_1$ | 42579.415 | 21.942 | 9722.92 | 19.510 | 6.77 |
| $M_2 I_3 S_2$ | 40291.198 | 29.664 | 9718.75 | 19.527 | 7.14 |
| $M_2 I_3 S_3$ | 36029.375 | 37.134 | 9722.92 | 19.694 | 7.43 |
| Grand Mean | 43861.100 | 32.299 | 9720.14 | 19.530 | 7.39 |
| SED | 254.8100 | 0.1887 | 9.4992 | 0.0766 | 0.1287 |
| CD @ 0.05 | 536.1200 | 0.3980 | 20.078 | 0.1643 | 0.2804 |
| Significance level | ** | ** | NS | NS | NS |

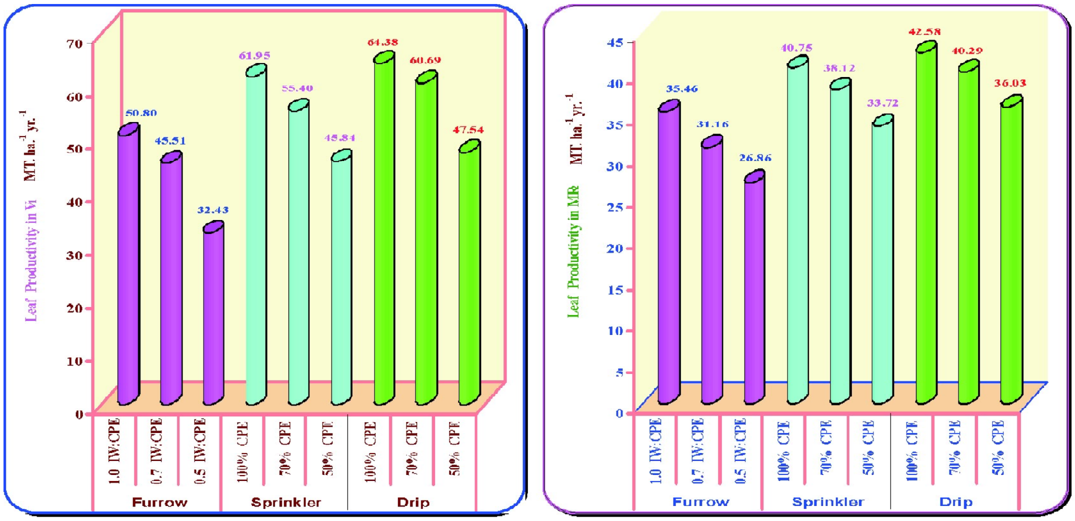


**Fig. 2 WUE farmers' practice, actual irrigation required & different system of water management in mulberry**

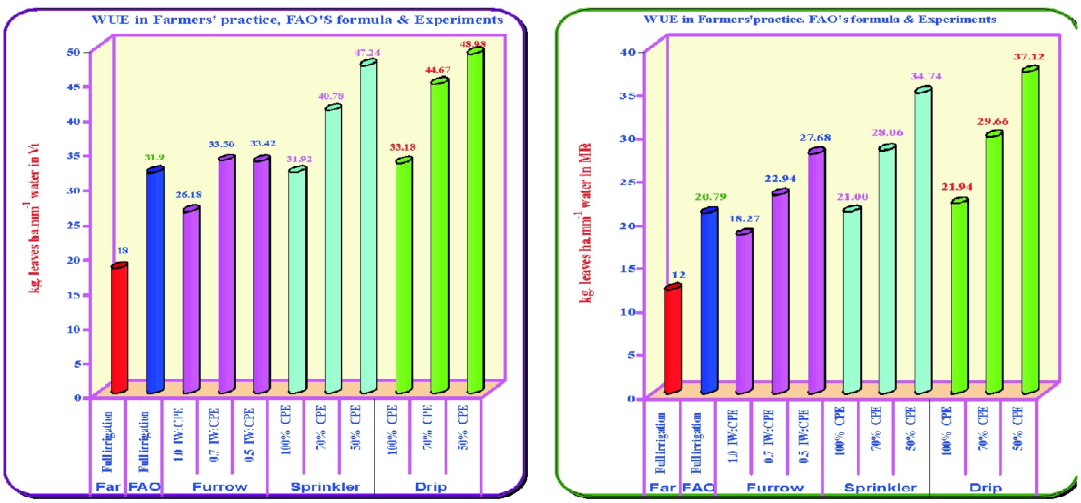


**Fig. 3 Average cost benefit ratio under different system of water management in mulberry crop**

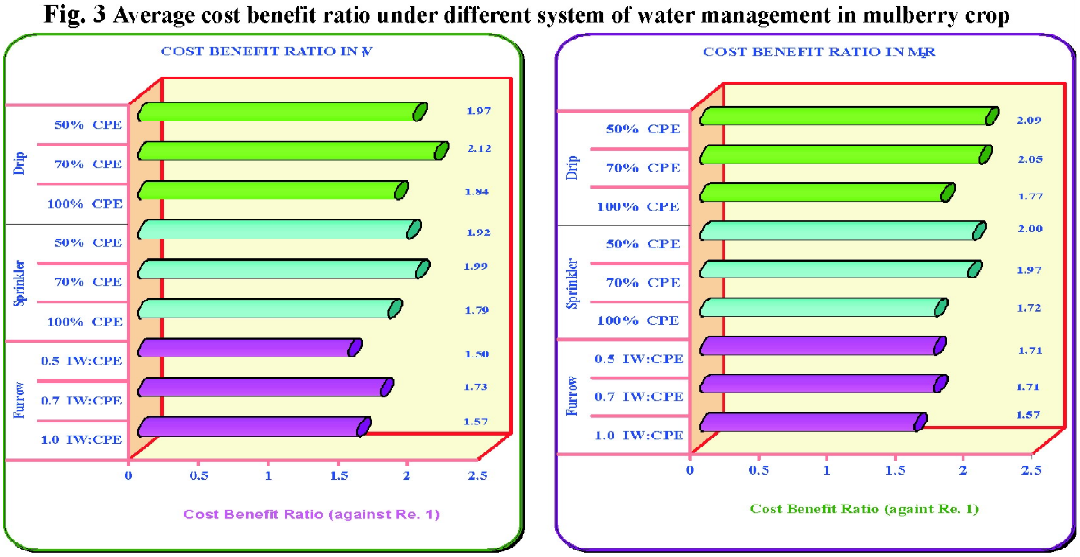


**Figure 1: Average leaf productivity under different system of water management in mulberry**

irrigation system is recommended for both the varieties. As the sustainable leaf productivity could achieved at reduced rate of irrigation water up to 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 which is **45.7 & 61.2 %** irrigation water savings in V1 & MR2 respectively when compared to the level of farmers' practice are recommended for effective utilization of irrigation water in mulberry cultivation.

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