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Weather Based Computation and Management of Irrigation Water For Mulberry Crop in Gangetic Alluvial Soil Under West Bengal Conditions

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Abstract: *Water is the most important input for better growth and productivity in mulberry crop without which other inputs ensured in the soil are not made available to plants. India with 28708 MT raw silk production stands second position next to China in the world and West Bengal with 2499 MT raw silk production occupies third position 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 2.20 lakh ha. area in India, of the total mulberry area above 80% is under irrigation conditions reflects the importance of irrigation for mulberry crop. As irrigation method adopted in mulberry crop by farmers of West Bengal is traditional open type i.e., flood irrigation system and the quantum of irrigation water applied is about 2" per irrigation of 10-12 days intervals without assessment of actual requirement for the crop results in poor Water Use Efficiency (WUE) and huge water loss due to conveyance, seepage and evaporation etc.,. In addition to the above excess water applied in mulberry crop reduces Fertilizer Use Efficiency (FUE) ultimately results in productivity loss.*

In order to appreciate the maximum efficiency of water utilized and save water in agriculture, modern efficient micro-irrigation systems like drip, sprinkler and precision method of irrigation etc., introduced are becoming popular and successfully used now a days have been followed in mulberry cultivation also. However most of the sericulture farmers in West Bengal are marginal groups with mulberry area in < 0.50 acre and with public common channel irrigation facilities as source of irrigation or under rain-fed cultivation are not feasible for adoption of micro-irrigation systems. Keeping in view of the above a study was conducted for consecutive two years to exploit maximum water use efficiency; save water and achieve quality linked productivity increase in mulberry crop. The field level experiment was drawn on Split Split Plot design in established high yielding mulberry variety (S1635) garden with two different spacing (S) i.e., 2′ × 2′ and Paired Row System (PRS) (5′ + 3′) × 2′ with five levels of irrigation water (I) scheduled at 50% SMD and applied in furrow method. Irrigation water equal to 2" per irrigation as control; irrigation water equal to 100% of ETc weather based computation in Cropwat 8 software following FAO's modified Penman Monteith formula on crop coefficient approach applied in all furrows; irrigation water equal to 80% 60% and 50% ETc applied in alternate furrows in 2′ × 2′ spacing and all furrows in paired rows of narrow spacing and thus a total of 10 treatments in 3 replications were maintained. The experiment was conducted for 4 crops in 4 different seasons per year for consecutive two years and the average results of the experiment revealed that the actual requirement of irrigation water for the crop was 30.52% less with 5.26 and 51.50% increased leaf productivity and WUE respectively as against the amount of irrigation water applied and leaf production and WUE obtained in farmers' practice. Irrigation level equal to 80% ETc in alternate furrows incase of 2′ × 2′ spacing and in all paired rows of narrow spacing in PRS with 44.42% less water and 70.44% improved WUE and with only –5.26% in leaf productivity without affecting the quality against farmers' practice may be considered as optimum irrigation water required for mulberry crop raised in Gangetic alluvial soil under West Bengal conditions. Though lower

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levels of irrigation treatments showed high WUE, sustainable leaf productivity was not maintained under open irrigation system in mulberry crop. In any levels of irrigation treatments leaf productivity in 2′ × 2′ spacing mulberry showed about 10.79% increased productivity. Studies on growth, productivity, quality parameters and WUE etc., of mulberry crop are discussed in detail in this paper.

Keywords: *Crop water requirement, Evapotranspiration of crop (ETc.,), Mulberry crop, Paired Row System, Soil Moisture Depletion(SMD), Sustainable productivity, Water Use Efficiency(WUE).*

INTRODUCTION

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 and energy and just 8% goes for domestic and commercial use (Anonymous, [2]). In India, agriculture sector uses about 93% of water whereas industry and domestic and commercial sectors use 3 and 4% respectively (Rakesh kumar *et al.,* [20]).

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, [16]).

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 2014-15, a total of 27,708 MT raw silk produced, employment opportunities to 8.03 million persons and foreign exchange of Rs. 2,829.88 crores earned for the country through silk goods export by the sericulture industry. Mulberry silk is the most popular one contributing around 74.51% of the total raw silk production of the country from 2.20 lakh ha. mulberry area covering 8.93 lakh sericulture families and 50,918 villages. Of the total mulberry silk of 21,389 MT produced in the country about 95% is produced from the traditional sericulture states namely Karnataka, Andhra Pradesh, West Bengal and Tamil Nadu (Anonymous, [3]). About 80 percent of mulberry garden in the country is under irrigated condition which shows the importance of irrigation for the mulberry crop.

Mulberry requires about 1.5-2.0″ acre water per irrigation at an interval of 6-12 days under traditional open flood irrigation system depending upon the type of soil and seasons. Requirement of irrigation water for mulberry crop was well studied by Naoi [14,15] and reported as equal to the value of Open Pan Evaporation [E_{pan}]. Mulberry amazingly response to irrigation water and fertilizer, withstand drought for short duration as rainfed crop and regain its production potential when sufficient water is available Rajaram *et al.,* [18]. About eight number of irrigation are 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, [8]; Gupta and Deshpande, [7]) our country is received in 4-5 months.

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 reported by Swaminathan, [28]. Importance of irrigation water in mulberry crop was studied in detail by Rajaram *et al.,* [18]. 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 reported by Ramasamy Iyyar, [21].

In the above context and in order to save irrigation water use with achievement of maximum Water Use Efficiency (WUE) in mulberry cultivation without any compromise on the quality and productivity of leaf holding the policy of "More Crop and Income for Drop of Water" upright this study was carried out on weather based computation of actual irrigation water requirement for mulberry crop using the FAO's modified Penman Monteith formula on crop coefficient approach in Gangetic alluvial soil under West Bengal conditions.

MATERIALS AND METHODS

The experiment was carried out in research mulberry farm established in Gangetic alluvial soil with S1635 improved high yielding variety in two different plant spacing *viz.*, 60 × 60 cms (S1) and Paired Row System (PRS) (S2) with spacing of (150+90) × 60 cm at CSR&TI., Central Silk Board, Berhampore, West Bengal during May 2013 to April 2015. The plants were pruned at a height of ¾ foot and 30 plots were demarked each with 5 rows and 8 plants and thus a total 40 No. of plants prescribed by Chaturvedi and Sarkar, [5] in Split split plot design described by Sukhatme and Amble, [27].

The experiment was drawn with 10 treatments of five levels of irrigation (I1 to I5) in both system of plantation and 3 replications each. In T1 2″ irrigation water (traditional farmers practice) applied in open flood check basin method; in T2, irrigation water equal to 100% ETc computed as per FAO's modified Penman Monteith formula described by Richard *et al.*, [23] applied in all furrows of 'U' shape channel; in T3, T4 and T5 irrigation water equal to 80; 60 and 50% ETc applied in alternate furrows of 'V' shape channel in plantation system 1 and similar treatments in PRS plantation (T6-T10); recommended dose of FYM @ 20 MT FYM ha^{-1} $year^{-1}$ in two equal split doses; chemical fertilizers NPK @ 336:180:112 kg. ha^{-1} $year^{-1}$ in equal split doses as recommended by Ray *et al.*, [22] applied in all crops under irrigated condition. ETc was computed using meteorological data collected from Automatic Weather Station, CSR&TI., Berhampore in Cropwat software on daily basis as described by Rajaram *and Qadri.*, [19] as per the formula given below:

$$ETo = \frac{0.408\Delta(Rn - G) + 900\ u2(es - ea) \over \gamma T + 273}{\Delta + \gamma(1 + 0.34\,u2)}$$

Where

ETo Reference evapotranspiration [mm da^{-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]

*u*2 Wind speed at 2 m height [m s^{-1}]

$Etc = ETo \times Kc$

$Kc = Kcb \times Ke$

ETc = Evapotranspiration of crop

Kcb : Basal crop coefficient;

Ke : Soil evaporation coefficient

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 $°C^{-1}$]

All other package of practices recommended for mulberry garden maintenance was followed as described by Dandin *et al.,* [6].

On 70^{th} day after pruning observations were made in all 30 plots under 10 treatments in 3 replications from 10 randomly selected plants on growth and yield parameters like number of branches/plant, branch height (cm), total shoot length/plant (m), number of leaves/branch, number of leaves/plant. total leaf weight/plant (kg), total shoot weight/plant (kg), green biomass weight/plant (kg), leaf yield ha^{-1} $crop^{-1}$ (MT), shoot weight ha^{-1} $crop^{-1}$ (MT), biomass green weight ha^{-1} $crop^{-1}$ (MT) and the yield was estimated as suggested by Sreenivasa Shetty *et al.*, [26]; moisture content and moisture retention capacity were found out as suggested by Vijayan *et al.*,[29]. All data of the experiments were subjected to statistical analysis using AGRES Software and the results are tabulated and discussed separately.

RESULTS AND DISCUSSIONS

Ananthakrishna *et al.*,[1] recommended 80% E_{pan} value of irrigation under drip scheduled alternate day for optimum leaf production in K2 mulberry. Similarly Mishra *et al.*,[10,11] reported 33% of water savings without affecting the yield under drip in K2 mulberry.

Several authors in several crops reported water savings under drip irrigation with increased productivity without affecting the quality of the product. Sivanappan *et al.*, [25] reported that 84.7% water saving under drip irrigation compared to conventional furrow irrigation without any adverse effects on growth, yield in Bhendi and this was confirmed by Sivanappan [24] in several vegetable crops like tomato, capsicum, okra, pawpaw and bananas with drip irrigation when compared to conventional surface irrigation at 50% Soil Moisture Depletion.

The average performances of the mulberry crop for the two experimental years conducted are discussed as below :

A) Growth Parameters (Table 1)

Number of branches/plant

The difference in average of branches per plant recorded in both plantation systems at irrigation levels are statistically non significant @ CD 5% level.

Branch height

Similarly the branch height and Total shoot length/ plant in both plantation system at irrigation was statistically non-significant @ CD 5% level.

No. of leaves/plant at harvest

As the difference in branch height and Total shoot length recorded in different treatments were statistically non-significant the same was reflected on number of leaves per plant also. The leaf yield difference among the different treatments was mainly due to leaf area and leaf thickness and number of plants per unit area.

Leaf yield ha^{-1} crop^{-1} (kg)

Leaf yield increase by 5.26% with 30.52% water savings and 51.50% WUE improvement in treatments with irrigation water equal to 100% ETc (T2 and T7) against farmers' practice (T1 and T6) were recorded. Similar results recorded in shoot weight and Total Green biomass weight and difference between the treatments was statistically significant @ CD 5% level. T2 and T7 exhibited highest biomass yield followed by T1 and T5 and least in T5 and T10. In T3 and T 8 water savings to a level of 44.42 % with 70.44% improvement on WUE with only 5.26% less leaf yield without loss in quality when compared to maximum record of yield observed in T2 and T7 were recorded. Though Water savings and WUE level recorded in T4 and T5; T9 and T10 were high leaf yield reduction upto 31.58% noticed.

Water Use Efficiency (kg leaves/m^3 water applied)

Average WUE of 2.442 (T2) and 2.179 (T6) in farmers' traditional irrigation practice are the lowest among all treatments may be due to more water applied over and above the irrigation water required by the crop and less productivity recorded in these treatments. Though WUE increases in lower level of irrigation water treatment the productivity per unit area has been considerably lowered. The WUE of 4.163 and 3.713 in T3; T8 treatments respectively with 70.44% improvements and 44.42% water savings are the optimum level irrigation water for sustainable productivity of the crop.

B) Leaf quality Parameters (Table 1)

Moisture Content of leaf (%)

The difference in moisture content and moisture retention capacity of leaf in various treatments recorded was statistically non-significant @ CD 5% level showed reduction irrigation water level only reflected on the productivity but not on the quality of leaves. similar response was reported by Parikh *et al.*, [17] in sugarcane.

Different factors contributing success for silkworm crop are studied in detail and mulberry leaf quality with 38.2% maximum contribution was reported by Miyashita, [12]; Benchamin *et al.*, [4] 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.*, [9] 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.

Muraleedhara *et al.*, [13] 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 and advancement in technologies have helped to increase the Cost

Table : 1 Showing the growth, yield, quality parameters and WUE under different treatments
(*Data average of eight crops in two consecutive years*)

Treatment	*Avg. branches/ plant (No.)*	*Avg. height of branch (cm)*	*Total shoot length/ plant (cm)*	*Avg. weight of leaf/ plant (g)*	*Avg. weight of shoot/ plant (g)*	*Avg. total biomass/ plant (g)*	*Avg. leaves/ plant (No.)*	*Avg. leaf yield ha^{-1} $crop^{-1}$ (kg)*	*WUE kg leaves/ m^3 water*	*Avg. total green biomass ha^{-1} $crop^{-1}$ (kg)*	*Avg. moisture content of leaf (%)*	*Avg. moisture retention capacity of leaf (%)*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
S_1I_1	9.33	121.19	1147.67	314.982	254.534	569.516	208.33	8749.570	2.442	15820.006	74.48	97.97
S_1I_2	11.33	117.42	1353.00	331.560	297.476	629.036	242.67	9210.074	3.700	17473.351	74.09	97.85
S_1I_3	9.33	111.54	1052.33	298.404	263.310	561.714	162.00	8289.066	4.163	15603.279	74.51	97.98
S_1I_4	9.33	120.86	1115.67	232.092	199.084	431.176	173.00	6447.052	4.317	11977.219	74.02	97.82
S_1I_5	9.00	125.29	1082.33	215.514	184.870	400.384	173.00	5986.548	4.810	11121.879	74.05	97.33
S_2I_1	18.67	93.12	1730.67	562.020	403.725	965.745	321.33	7805.896	2.179	13412.268	76.98	98.31
S_2I_2	19.00	85.56	1623.33	591.600	386.488	978.088	348.67	8216.732	3.301	13583.685	76.66	98.41
S_2I_3	19.33	87.68	1690.33	532.440	349.448	881.888	306.67	7395.059	3.714	12247.657	77.22	97.96
S_2I_4	15.33	102.46	1567.33	414.120	294.471	708.591	267.67	5751.713	3.851	9840.918	77.44	98.18
S_2I_5	17.67	100.22	1558.67	384.540	273.438	657.978	267.67	5340.876	4.292	9137.992	77.16	98.11
SEd	1.3824	29.2743	194.0338	6.4321	12.9322	15.6540	47.2821	91.1268	0.0345	285.1921	0.4980	0.2218
Signi.level	NS	NS	NS	**	**	**	NS	**	**	**	NS	NS
CD@ 5%	2.9798	11.4189	448.6506	13.7041	33.6562	38.4051	102.9113	193.2625	0.0786	746.4199	1.5465	0.5333

Water Use Efficiency (kg leaves/m^3 water used)

Benefit ratio to a higher level by 1:2.12 and 1:1.99 in V1 and MR2 mulberry varieties respectively was reported by Rajaram and Qadri, [19]. Ananthakrishna *et al.*, [1] 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.

CONCLUSIONS

It is concluded from the results of the study that the farmers' traditional flood irrigation system in mulberry cultivation not only requires more irrigation water than the actual requirement of irrigation water of the crop but also affected the unit area leaf productivity in mulberry. Irrigation water equal to 100% ETc application in furrows method which is about 30.52% less than the irrigation water used in farmers' practice is the actual irrigation water required by the crop. Further in the open irrigation method itself with simple modification in irrigation channel shape as 'V' and application of irrigation water in alternate furrows in 60 x 60 cm spacing and in between paired rows in narrow spacing of PRS plantation, irrigation water equal to 80% ETc which is almost 44.42% less than the farmers' practice and with 70.44% improvement on WUE without affecting the productivity and quality of leaf may considered as optimum level irrigation water for mulberry crop.

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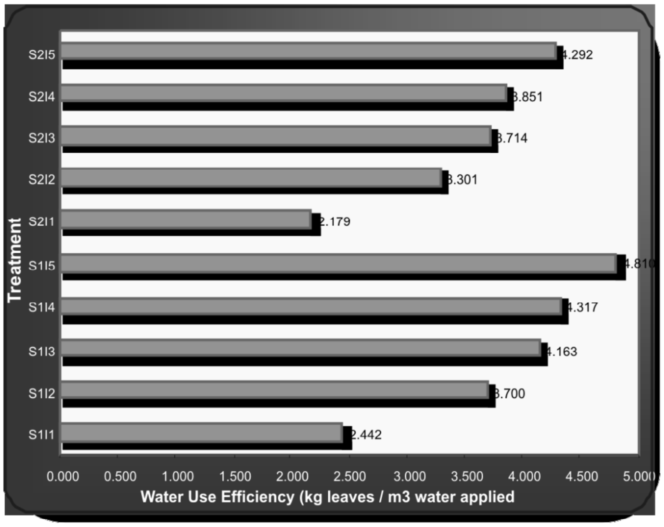

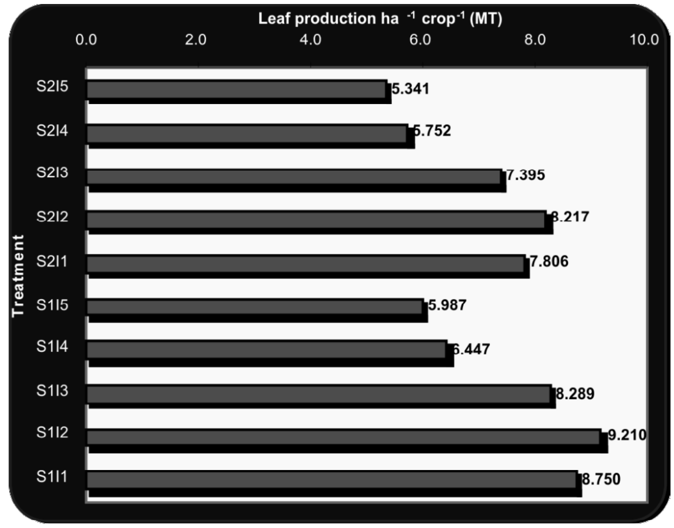

Figure : 1 and 2 Water Use Efficiency and Leaf productivity in mulberry crop recorded in the experiment

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