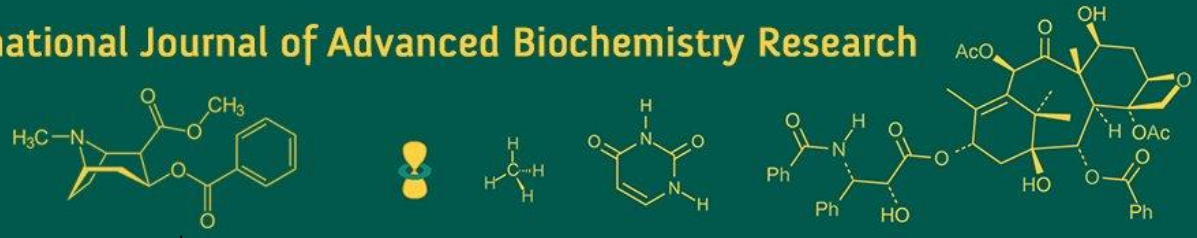
International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(8): 1093-1097
www.biochemjournal.com
Received: 20-05-2024
Accepted: 30-06-2024

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Impact of mulberry irrigated with reeling effluent on rearing performance of silkworm and cocoon production

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DOI: https://doi.org/10.33545/26174693.2024.v8.i8n.1957

Abstract
A field experiment was conducted during 2022-2023 at Department of Sericulture, UAS, GKVK, Bengaluru to know the effect of feeding of mulberry irrigated with different combinations reeling effluent and borewell water on silkworm and cocoon production. Among all the treatments application of 100 per cent reeling effluent irrigated mulberry fed silkworm performed better. This resulted in notable enhancements, including increased larval weight (33.22 g/10 larvae), higher Effective rate of rearing (99.00%) and shorter fifth instar larval duration (186.69 h). The cocoon parameters *viz*., single cocoon weight (1.67 g), pupal weight (1.37 g), shell weight (0.30 g) and cocoon shell ratio (18.46%). The reeling parameters *viz*., average filament length (831.48 m) and filament weight (0.27 g) were significantly higher in silkworm fed with mulberry leaves raised by reeling effluent irrigation along with the recommended dosages of fertilizer and Farm yard manure.

Keywords: Reeling effluent, silkworm, cocoon

Introduction
Mulberry is a fast growing deciduous woody perennial plant having deep root system, grown under varied climatic conditions ranging from temperate to tropical region. The total area under mulberry cultivation in India is about 2.42 lakh hectare. In Karnataka, about 80 per cent of the mulberry region is under the irrigated condition and high yielding mulberry variety (V1) is being cultivated (Anonymous, 2022) [1]. Vegetative part is the main component of mulberry, which is influenced by mulberry cultivars, environmental factors, different kinds of soil, chemical fertilizers, methods of irrigation, ideal plant spacing, plant population, appropriate pruning schedules and proper harvesting techniques are some of the crucial elements that encourage production of high-quality leaves. Among these factors irrigation also plays a significant function in improving the quality and quantity of mulberry leaves which directly affects the growth and development of silkworm (Kalpana *et al*., 2018) [7]. Silk production, a critical industry in many parts of the world, relies heavily on the optimal growth of mulberry trees and the health of silkworms, which are fed exclusively on mulberry leaves. The quality of mulberry leaves directly influences the growth, health, and productivity of silkworms, ultimately impacting the yield and quality of silk produced. Traditional irrigation methods for mulberry cultivation often involve the use of freshwater resources, but the increasing scarcity of water and the rise of wastewater recycling have prompted the exploration of alternative irrigation practices. One such practice is the use of reeling effluent, which typically contains organic matter and nutrients—as an irrigation source for mulberry trees. This approach presents a potential dual benefit: it could alleviate water scarcity issues and enhance the fertility of the soil through the recycling of nutrients. However, the impact of reeling effluent on mulberry cultivation and silkworm rearing is not well-documented, necessitating a detailed investigation. This study aims to explore the effects of mulberry irrigation with reeling effluent on the rearing performance of silkworms and the subsequent cocoon production. By examining how this unconventional irrigation method influences silkworm health, and cocoon yield. These findings could offer valuable insights into sustainable silk production and wastewater management, potentially leading to more efficient and environmentally friendly practices in sericulture.

Materials and Methods

An investigation entitled "Impact of reeling effluent irrigation on the performance of mulberry and its impact on cocoon production" was carried out in the Department of Sericulture, College of Agriculture, GKVK, Bengaluru. The primarily reeling effluent was collected from Bagalur reeling unit and mixed that in water tank as per treatments and irrigated to mulberry crop according to the treatment combination. The total water requirement for mulberry cultivation under red sandy loamy soil is 13,51,350 liters per crop. The mulberry crop was irrigated through flood irrigation system once in 7 days for 70 days (totally 10 irrigations) (Dandin and Giridhar 2014) [5]. The calculated total water requirement was 1,15,500 liters for 342 m^2 area in entire crop duration.

Treatment details

Treatments	Treatment details
T_1	100% bore-well water
T_2	25% reeling effluent + 75% bore-well water
T_3	50% reeling effluent + 50% bore-well water
T_4	75% reeling effluent + 25% bore-well irrigation
T_5	100% reeling effluent

Note: NPK and FYM applied has per recommendation.

Field Experiment was conducted during March 2022 to May 2023 laid out as per Randomized Complete Block Design (RCBD). Each treatments were replicated four times. The silkworm PM×CSR_2 was used for the experiment. A sample consisting of ten worms selected from each treatments and recorded various observation.

Results and Discussion

1. Impact of reeling effluent irrigation on rearing performance of late age silkworm (PM × CSR_2)

Silkworms were fed with mulberry leaves sourced from the V1 mulberry garden with recommended dose of NPK (kilograms per hectare per year) in combination with FYM and irrigated with reeling effluent, it was observed that this approach had a positive impact on the late-age silkworms. However, various parameters, including fifth instar larval weight, fifth instar larval duration, effective rate of rearing, mortality percentage, cocoon characteristics, and reeling parameters, displayed notable differences among the different treatments.

Fifth instar larval weight (g/10 larvae)

There were significant variations in the fifth instar larval weight when silkworms were fed with leaves from different plots irrigated with reeling effluent. The highest fifth instar larval weight (33.22 g/10 larvae) was recorded in T_5 (100% reeling effluent irrigation) followed by T_4 (75% reeling effluent + 25% borewell water) (32.48 g/10 larvae). In contrast, the lowest fifth instar larval weight (29.25 g/10 larvae) was recorded in (100% borewell water irrigation) (Table 1).

The present investigation recorded higher larval weight (33.22 g/10 larvae) which was align with Chikkaswamy *et al*. (2014) [4] recorded a notable increase in the fifth instar larval weight (3.01 g/larvae) among the NB_4D_2 larvae when they were nourished with leaves harvested from plot irrigated with raw sewage water

Fifth instar larval duration (h)

There were significant variations in the fifth instar larval duration when silkworms were fed with leaves from different plots irrigated with reeling effluent. The shortest fifth larval duration (186.69 h) was observed when the silkworms were fed with mulberry leaves from plots irrigated with 100 per cent reeling effluent which is followed by T_4 (Irrigation with 75% reeling effluent + 25% borewell water) (187.75 h). In contrast, the longest fifth larval duration (191.63 h) was noted when the silkworms were fed with mulberry leaves from plots irrigated with 100 per cent borewell water (Table 1).

Similar findings were reported by Bongale and Krishna (2000) [2] reported that mulberry leaves with higher nutritional status (sugars, amino acids, soluble protein and chlorophyll) may have stimulated the metabolic activities of silkworms shortening their larval stage. Similarly, Shankar (1990) [13] also recorded that earlier maturation due to quicker metabolic activity and balanced nutritional quality of the leaves which shortens the larval duration.

Larval mortality (%)

There was zero per cent mortality observed in all the treatment combination.

Table 1: Growth parameters of PM × CSR_2 as influenced by feeding mulberry leaf from reeling effluent irrigated mulberry garden

Treatments	V instar larval weight (g/10 larvae)	V instar larval duration (h)	Mortality (%)	Effective rate of rearing (%)
T_1- 100% bore well water irrigation (control)	29.25	191.63	0.00	94.00
T_2- 25% reeling effluent + 75% bore well water irrigation.	30.38	189.25	0.00	95.50
T_3- 50% reeling effluent + 50% bore well water irrigation	30.81	188.25	0.00	97.00
T_4- 75% reeling effluent + 25% bore well water irrigation	32.48	187.75	0.00	97.50
T_5- 100% reeling effluent irrigation	33.22	186.69	0.00	99.00
F-test	*	*	NA	*
S. Em ±	0.62	0.95	-	0.71
$CD_{0.05}$	1.91	2.92	-	2.20

Note: *Significant at 5%

Effective rate of rearing (ERR)

There were significant variations in the effective rate of rearing when silkworms were fed with leaves from the plots irrigated with reeling effluent. The higher effective rate of rearing (99.00%) was observed when the silkworms were fed with mulberry leaves from T_5 (Irrigation with 100% reeling effluent) which was followed by T_4 (Irrigation with 75% reeling effluent + 25% borewell water) (97.50%). In contrast, the lowest effective rate of rearing (94.00%) was recorded when the silkworms were fed with mulberry leaves from T_1 (Irrigation with 100% borewell water) (Table 1).

Similar findings were reported by Shankar (1990) [13] feeding of silkworms with leaves that are nutritionally superior may be the cause of the increase in ERR.

According to Rao *et al*. (2010) [10] sewage water significantly affected the production of three amino acids (threonine, methionine and histidine) which enhances silkworm growth and development.

2. Cocoon parameters of PM×CSR$_2$ as influenced by feeding mulberry leaf from reeling effluent irrigated mulberry garden.

Single cocoon weight (g)

There was significant difference in single cocoon weight when silkworms were fed with leaves from plots irrigated with reeling effluent. The highest single cocoon weight (1.67 g) was observed when silkworms were fed with mulberry leaves from T_5 (100% reeling effluent irrigation) which was followed by T_4 (75% reeling effluent + 25% borewell water irrigation) (1.54 g). In contrast, the lowest single cocoon weight (1.30 g) was recorded when silkworms were nourished with mulberry leaves from T_1 (100% borewell water irrigation) (Table 2) (Fig 1).

The current study the PM×CSR$_2$ hybrid exhibited a significantly higher single cocoon weight (1.67 g) which was supported by Saad (2014) [12] reported that maximum single cocoon weight of (1.48 g) was recorded when silkworms were fed with mulberry leaves irrigated with raw sewage water. The present findings align with the previous research of Bongale and Krishna (2000) [2] as well as Ravindra Chary (2000) [11].

Pupal weight (g)

There were significant variations in the pupal weight when silkworms were fed with leaves from plots irrigated with reeling effluent. The highest pupal weight (1.37 g) was recorded in T_5 (100% reeling effluent irrigation) followed by T_4 (75% reeling effluent +25% borewell water irrigation) (1.27 g). In contrast, lowest pupal weight (1.07 g) was noted in T_1 (100% borewell water irrigation) (Table 2).

In the current study, the PM × CSR$_2$ exhibited a significantly higher pupal weight (1.37 g) which was supported by Saad (2014) [12] reported that maximum single pupal weight (1.288 g) associated with the irrigation of raw sewage water. These current findings also align with Bongale and Krishna (2000) [2], Chikkaswamy *et al*. (2014) [4] and Paramanik (2015) [9] collectively suggesting a consistent pattern of higher pupal weight in silkworms under specific irrigation conditions.

Shell weight (g)

There was significant difference in single shell weight when silkworms were fed with leaves from plots irrigated with reeling effluent. The highest single shell weight (0.30 g) was observed when silkworms were fed with mulberry leaves from T_5 (Irrigation with 100% reeling effluent) which was followed by T_4 (Irrigation with 75% reeling effluent + 25% borewell water) (0.27 g). In contrast, the lowest single shell weight (0.21 g) was recorded when silkworms were nourished with mulberry leaves from T_1 (Irrigation with 100% borewell water) (Table 2) (Fig 1).

Observed that cocoon shell weight is a crucial quality parameter that is significantly affected by quality of leaves. Similarly, Ravindra Chary (2000) [11] reported a significantly higher cocoon shell weight (0.35 g) when sewage effluent from the Vrishabhavathy river was utilized with recommended dose of FYM and NPK (nitrogen, phosphorus and potassium). These findings align with the earlier research of Bongale and Krishna (2000) [2] and Paramanik (2015) [9], indicating a consistent pattern of increased cocoon shell weight under specific conditions.

Table 2: Cocoon parameters of PM×CSR$_2$ as influenced by feeding of mulberry leaf from reeling effluent irrigated mulberry garden

Treatments	Single cocoon weight (g)	Pupal weight (g)	Single shell weight (g)	Cocoon shell ratio (%)	Cocoon yield by weight (kg/10000 cocoons)
T_1- 100% bore well water irrigation (control)	1.30	1.07	0.21	16.62	13.03
T_2-25% reeling effluent + 75% bore well water irrigation.	1.42	1.17	0.24	17.21	14.19
T_3-50% reeling effluent + 50% bore well water irrigation	1.50	1.24	0.26	17.33	15.05
T_4-75% reeling effluent + 25% bore well water irrigation	1.54	1.27	0.27	17.47	15.42
T_5-100% reeling effluent irrigation	1.67	1.37	0.30	18.46	16.75
F-test	*	*	*	*	*
S. Em ±	0.04	0.04	0.007	0.32	0.47
$CD_{0.05}$	0.14	0.12	0.02	0.99	1.45

Note: *Significant at 5%

Cocoon shell ratio (%)

There were significant variations in the cocoon shell ratio when silkworms were fed with leaves plots irrigated with reeling effluent. The highest cocoon shell ratio (18.46%) was recorded when silkworms fed with mulberry leaves from T_5 (Irrigation with 100% reeling effluent) which was followed by T_4 (75% reeling effluent + 25% borewell water irrigation) (17.47%). In contrast, the lowest cocoon shell ratio (16.62%) was recorded when silkworms nourished with mulberry leaves from T_1 (Irrigation with 100% borewell water) (Table 2) (Fig 1).

In the current study, the PM × CSR$_2$ hybrid exhibited a significantly higher shell ratio (18.46%) can be compared with study conducted by Saad (2014) [12] recorded higher shell ratio (20.0%) in raw sewage irrigation. Similarly, Chikkaswamy *et al*. (2014) [4] also reported an increased shell ratio (22.77%) in the NB$_4$D$_2$ variety when mulberry leaves were irrigated with raw sewage water. In addition, Ravindra Chary (2000) [11] recorded significantly higher shell ratio of (20.7%) when sewage effluent from the Vrishabhavathi river irrigated with recommended dose of FYM and NPK.

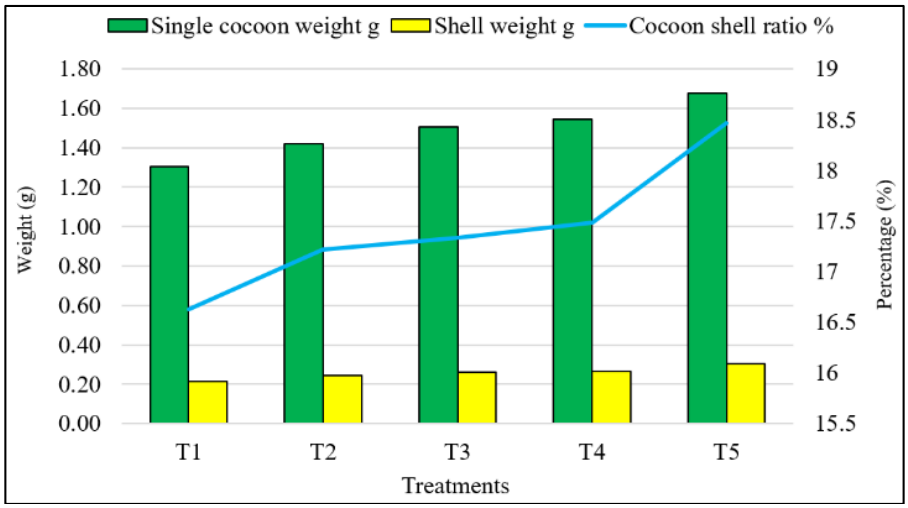

Fig 1: Influence of reeling effluent irrigation on cocoon weight, shell weight and cocoon shell ratio 3 Silk parameters of PM×CSR_2 as influenced by feeding mulberry leaf from reeling effluent irrigated mulberry garden

Filament length (m)

Notable difference in filament length was evident when silkworms were fed with leaves from plots irrigated with reeling effluent. The longest filament length (831.48 m) was observed when silkworms were fed with mulberry leaves from T_5 (100% reeling effluent irrigation) which was followed by T_4 (75% reeling effluent + 25% borewell water irrigation) (825.01 m). In contrast, the shortest filament length (804.20 m) was recorded when silkworms were nourished with mulberry leaves from T_1 (100% borewell water irrigation) (Table 3).

The results of current findings supported by Kumar and Chandrashekhar (2020) recorded that significantly longer filament length (853.00 m) and higher filament weight (0.28 g) in silkworms fed with mulberry leaves from the plots irrigated with raw sewage water. Similarly, Chandraju *et al*. (2012) [3] reported significantly longer filament length (800.00 m, 868.35 m and 878.34 m) in three distinct breeds of silkworms (CSR 18, CSR 19 and Kolar gold) when mulberry irrigated with distillery. Further noted that spent wash irrigation contributed to the enrichment of nutritional content in mulberry leaves, subsequently improved silkworm growth and development this in turn resulted in higher proportions of silk proteins led to the spinning of longer silk threads.

Filament weight (g)

There was significant difference in the filament weight when silkworms were fed with leaves from plots irrigated with reeling effluent. The highest filament weight (0.27 g) was observed when silkworms were fed with mulberry leaves from T_5 (100% reeling effluent irrigation) which was followed by (0.25 g) T_4 (75% reeling effluent + 25% borewell water irrigation). In contrast, the lowest filament weight (0.21 g) was recorded in T_1 (100% borewell water irrigation) (Table 3).

Similar results were reported by Chandraju *et al*. (2013) recorded significantly higher filament weight when mulberry irrigated with distillery spentwash. The findings of the present study about cocoon parameters in line with Bongale and Krishna (2000) [2].

Denier

The denier was found non-significant when silkworms were fed with leaves from plots irrigated with reeling effluent. However, higher denier (2.92) was observed when silkworms were fed with mulberry leaves from T_5 (100% reeling effluent irrigation) whereas, lower denier (2.35) was recorded when silkworms were nourished with mulberry leaves from T_1 (100% borewell water irrigation) (Table 3).

The comprehensive assessment of silkworm performance across all parameters revealed that the utilization of reeling effluent for irrigation has a positive impact on larval development, cocoon quality and silk related characteristics. These results underscore the direct correlation between the superior nutrient content of the leaves and well-being of the silkworms, ultimately leading to enhanced cocoon parameters. As literature available are limited the results of current findings are compared with those of Surendranath *et al*. (1997) [14], who reported significant improvements in the quality parameters of M-5 mulberry leaves when irrigated with sewage water compared to borewell water, resulting in an overall enhancement of cocoon characteristics in the silkworms.

Table 3: Silk parameters of PM×CSR_2 as influenced by feeding mulberry leaf from reeling effluent irrigated mulberry garden

Treatments	Filament length (m)	Filament weight (g)	Denier
T_1- 100% bore well water irrigation (control)	804.20	0.21	2.35
T_2-25% reeling effluent + 75% bore well water irrigation.	809.55	0.22	2.52
T_3-50% reeling effluent + 50% bore well water irrigation	815.73	0.23	2.60
T_4-75% reeling effluent + 25% bore well water irrigation	825.01	0.25	2.83
T_5-100% reeling effluent irrigation	831.48	0.27	2.92
F-test	*	*	NS
S. Em ±	5.84	0.01	-
$CD_{0.05}$	18.01	0.02	-

Note: * Significant at 5%; NS- Non-Significant

Conclusion

In conclusion, the impact of feeding mulberry leaves irrigated silk reeling effluent and borewell water on silkworm and cocoon is significant. Through this study, it has been elucidated that feeding of mulberry leaves irrigated with reeling effluent and borewell water significantly increases the silkworm parameters. The Cross Breed silkworm PM x CSR_2 hybrid showed a positive response when nourished with mulberry leaves cultivated using 100 per cent reeling effluent irrigation. This resulted in notable enhancements, including increased larval weight, higher Effective rate of rearing and shorter fifth instar larval. The cocoon parameters *viz.*, single cocoon weight, pupal weight, shell weight and cocoon shell ratio were significantly higher in silkworm fed with mulberry leaves raised by reeling effluent irrigation along with the recommended dosages of fertilizer and Farm yard manure. The reeling parameters *viz*., average filament length and weight was significantly higher in silkworms fed with mulberry leaves raised by 100 per cent reeling effluent irrigation whereas, denier was found non-significant among different treatments.

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