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Research Article

Optimal Date of Mulberry Pruning and Silkworm Rearing for Improvement of Quality and Yield Potential of Mulberry Foliage and Silk Cocoons in Lower-Gangetic Region

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Abstract

Mulberry sericulture is an alternative farm-based livelihood activity and is practiced in various climatic conditions. A field and rearing experiment was conducted to evaluate the mulberry variety S-1635 for leaf and silk cocoon productivity under alternative pruning and rearing schedule during autumn 2019 and spring 2020 seasons. The leaf moisture content, leaf fall at harvest, primary shoots plant^{-1}, longest shoot length, total shoots length and leaf yield plant^{-1} was significantly higher in new pruning schedule in both the season. The new mulberry crop schedule recorded higher leaf productivity to a tune of 12% in autumn and double in comparison to existing schedule practiced by farmers. The role of optimal weather and period of crop growth had a greater impact on leaf yield during autumn and spring crops, respectively. Most of the reeling cocoon and silk parameters obtained from fed leaves differed significantly with pruning schedules in both the seasons. Effective rate of rearing and weight was significantly higher in new pruning schedule while single cocoon weight was higher in existing schedule. The new silkworm rearing schedule recorded 10-12% higher cocoon yield in both Agrahayani (75.67 kg) and Falguni (62.08 kg) crops compared to existing crop schedule. The investigation revealed that delaying the mulberry pruning and silkworm rearing date by two weeks effectively increased both leaf and cocoon output. The new mulberry sericulture crop schedules will be a climate change adaptation strategy to maintain production potential in the lower-gangetic region.

Keywords: Mulberry, Pruning, Rearing, Silkworm, Weather

Introduction

The science of sericulture is concerned with raising silkworms for the purpose of producing raw silk for the textile industry. Sericulture and silk industry stands for livelihood opportunity for millions and most suitable avenues for socio-economic development in rural areas. At present, consumption of silk goods increasing in most of the developed countries leads to high demand in the global market. India ranks second in both silk production and consumption. Mulberry is grown on 2.42 lakh ha and produces of 25,818 tons of mulberry silk during 2021-22 (Anonymous, 2022). Mulberry silk is the most popular among five varieties of commercial silk, which contributes to around 75% of the country's total silk production (34,903 MT). Mulberry is the sole feed of *Bombyx mori* and grown in a variety of climates, from temperate to tropical. Further, mulberry foliage is a major economic component in sericulture since the quality and quantity of leaf produced per unit area have a direct bearing on cocoon output (Datta, 2000). In subtropical climates, the plants remain dormant during December to mid January. Mulberry stumps starts sprouting in spring (mid January), when the temperature reaches 13 °C and produces leaves continuous for rearing throughout the year. West Bengal is major traditional silk producing state in India and mulberry silkworm rearing is a seasonal activity. The silkworm rearing seasons are mainly

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divided in two parts *i.e.*, November (autumn or Agrahayani) and February crop (spring or Falguni) fall under the favoured season, while April (summer or Baishaki), June-July (Shrabani), and August-September crops (Ashwina) fall under the unfavored season (Sarkar, 2018). Mulberry crop span is 70 days and five shoot harvests as well as five silkworms rearing is done in a year at fixed schedules. The mulberry silkworm (*Bombyx mori* L.) is extremely susceptible to changes in the environment. Temperature, humidity, rearing seasons, the quality of mulberry leaves, and the genetic makeup of particular silkworm breeds all have a significant impact on the growth and development of silkworm larvae as well as the economic characteristics of cocoons. The seasonal variations in environment will also have a significant impact on the productivity of cocoons and silk (Sarkar, 2018). Environmental changes over the past ten years have highlighted the need for management strategies to ensure sustainable mulberry cocoon production. Timely mulberry pruning and silkworm rearing provides optimum growing period for the mulberry and silkworm which leads to more foliage biomass and higher quality cocoon output. Keeping the above facts in consideration, the current experiment was conducted in autumn and spring season of 2019 to 2020, to study the effect of alternate mulberry pruning and silkworm rearing dates on foliage and cocoon yield performance of popular variety S-1635.

Materials and Methods

Field and silkworm bioassay experiments were carried out during the year September 2019 to march 2020 in Central Sericultural Research and Training Institute, Berhampore, West Bengal. The study site has a humid subtropical climate, gangetic alluvial soil with a pH of 6.9, EC of 0.12 m mhos cm^{-1}, and an organic carbon content of 0.56% is located at an altitude of 19 m above mean sea level (34°0'28" North, 71°34'24" East). The existing and alternate mulberry pruning date (PD) and silkworm rearing date (RD) in two crop seasons are given in table 1. The two dates of mulberry pruning and silkworm rearing are the two treatments making new and existing mulberry and silkworm crop schedules. Ten-year-old S-1635 plantation was used in the field experiment, which was set up in complete block design with three replications at 90×90 cm spacing. The crop was raised with recommended agronomic practices under low trunk non-fist plantation system. Observations were recorded on eight leaf quality parameters such as total chlorophyll content (TCC), total soluble protein (TSP), total soluble sugars (TSS), fresh leaf moisture content (LMC), moisture retention capacity (MRC), specific leaf area (SLA), chlorophyll content index (CCI) by CCM-200 (Optic science), and leaf fall at harvest (LFH) along with nine morphological traits *viz*., fresh leaf weight (FLW), fresh leaf area (FLA), leaves per meter shoot (LMS), length of the longest shoot (LLS), number of primary shoots $plant^{-1}$ (NPS), total shoot length (TSL), shoot yield $plant^{-1}$ (SYP), leaf to shoot ratio (LSR), leaf yield $plant^{-1}$ (LYP) and leaf yield ha^{-1} (LYH). The productivity of leaf yield was recorded per plot and obtained leaf yields were converted into kg ha^{-1}.

Silkworm rearing was carried out in complete block design with six replications using popular hybrid SK6 × SK7 which was feed by the S-1635 leaves obtained in two different pruning dates or crop schedules (Table 1). The silkworm rearing was carried out in a typical rearing house and maintained in ideal environmental conditions as per guidelines (Dandin and Giridhar, 2010). The rearing room along with rearing accessories was properly disinfected with 5% bleaching powder solution as per recommendations of Dandin *et al.* (2003). The chawki worms were feed with tender leaves in plastic trays for three times a day (7.00 AM, 12.00 PM and 4.00 PM) and late age worms were fed with entire shoots. According to the silkworms' ages, the ideal spacing was maintained and bed cleaning was as done as needed. The bed disinfectants lime powder and Labex or Vijetha were dusted on silkworm before and after moulting, respectively (Dandin and Giridar, 2010). The fresh cocoons were harvested on sixth day after mounting and evaluated different cocoon parameters. Silk reeling parameters were analyzed as per standard procedure in the reeling and silk

Table 1: Mulberry pruning dates (PD) and silkworm rearing dates (RD) in two crop seasons during 2019-20

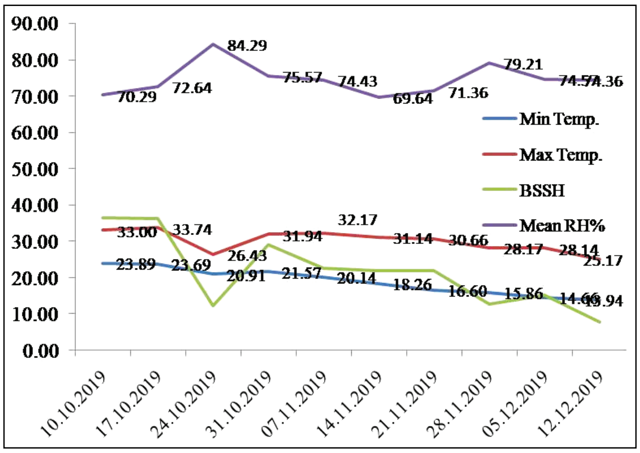
Mulberry Crop	Particular	Pruning Date		Silkworm Crop	Particular	Rearing Date	
		PD-1	PD-2			RD-1	RD-2
Autumn 2019	Date of Pruning	19th September	10th October	Agrahayani 2019	Date of Brushing	31st October	20th November
	Date of Harvesting	1st December	15th December		Date of Harvesting	24th November	15th December
	Crop duration	70 days	70 days		Crop duration	25 days	26 days
Spring 2020	Date of Pruning	1st December	15th December	Falguni 2020	Date of Brushing	30th January	15th February
	Date of Harvesting	25th February	14th March		Date of Harvesting	24th February	14th March
	Crop duration	87 days	89 days		Crop duration	26 days	28 days

testing lab of the institute. The outdoor weather parameters during new and existing mulberry crop schedules are shown in figure 1. The data analysis tool package of MS Excel 2007 programme was used for analysis. Differences among two pruning and rearing dates were determined by paired 't-test' for two sample means at $p \leq 0.05$.

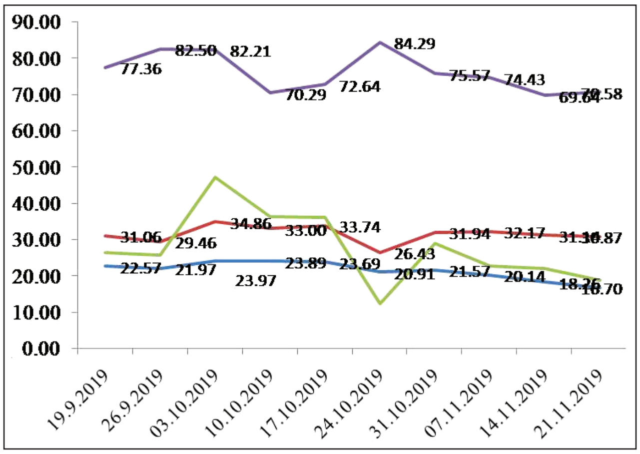
Results and Discussion

Mulberry Leaf Quality and Yield in Alternate Date of Pruning

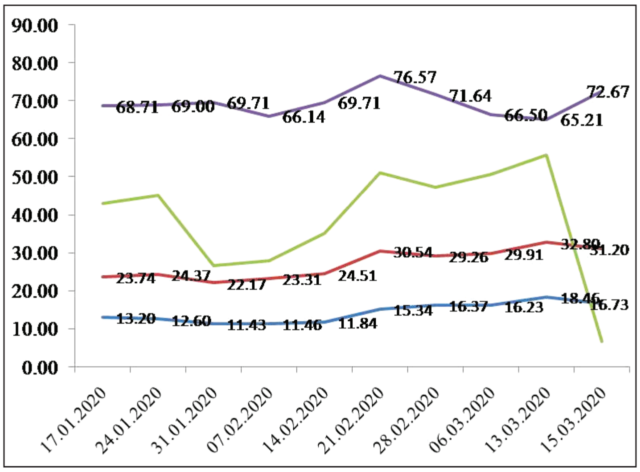
Climate change continues to be a major concern of present century and global warming has significantly impacted sericulture production (Neelaboina *et al.*, 2018). Climate change affecting the timing and length of crop seasons (Shah *et al.*, 2021). Mulberry pruning as per local climatic conditions is a common adaptation practice, but no information is known about it effectiveness. Further, climate (37.0%) and mulberry leaf (38.2%) are the major factors contributing for the successful cocoon crop production followed by management skills (9.3%), silkworm hybrid (4.2%) and other factors (Miyashitha, 1986). The delayed pruning of autumn season due to increased temperature and delayed harvesting in spring season due to longer period of cold will be an important adaptation measure for improving quality mulberry leaf production in these two



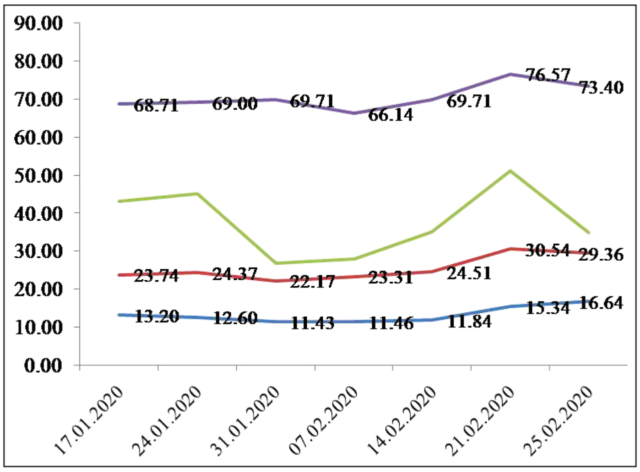
a) Mulberry Autumn crop: New pruning date



b) Mulberry Autumn crop: Existing pruning date



c) Mulberry Spring crop: New pruning date



d) Mulberry Spring crop: Existing pruning date

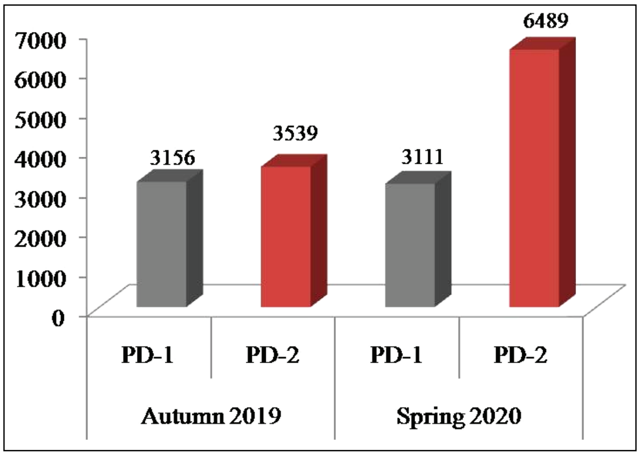
Figure 1: Outdoor weather parameters during new and existing mulberry crop schedules

seasons. In the present investigation, mean performance of two mulberry pruning dates on leaf quality and yield in different seasons are given in table 2. The analysis of data revealed that mulberry plants pruned on alternate date recorded significantly higher leaf moisture content (78.01%), total soluble protein (31.65 mg g^{-1}), soluble sugars (32.73 mg g^{-1}), lower leaf fall (10.52%), longest shoot length (104 cm), total shoots length (920 cm) and leaf yield $plant^{-1}$ (287 g) than existing pruning schedule. These results are in similar for mulberry growth parameters obtained by Pawan *et al.* (2017). The alternate date of pruning was found to be effective in improvement of leaf moisture quality and leaf productivity in autumn season 2019. However, Pawan *et al.* (2017) reported that no significant alteration in growth parameters of mulberry by different times of pruning. During spring season 2020, delayed harvesting found to significantly increase the leaf moisture content, specific leaf area, total soluble protein, total soluble sugars, growth traits and leaf yield $plant^{-1}$. Higher mean leaf moisture content (76.33%), moisture retension capacity (80.77%), total soluble sugars (34.17 mg g^{-1}), longest shoot length (104 cm), total shoots length (1012 cm) and leaf yield $plant^{-1}$ (518 g) were recorded

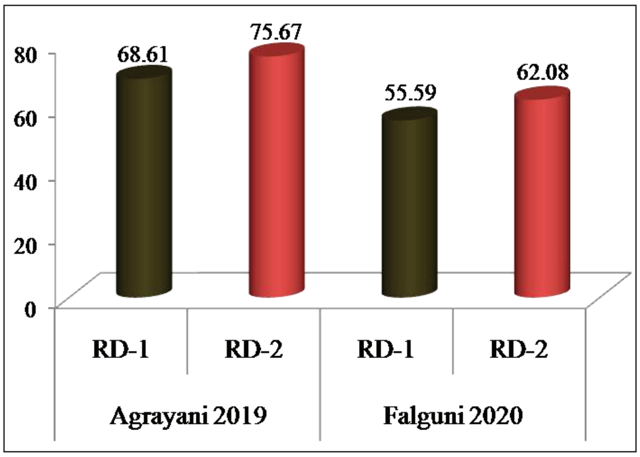
Table 2: Mean performance of two mulberry pruning dates on leaf quality and yield in different seasons

Mulberry crop seasons	Autumn season 2019			Spring season 2020		
Traits/ Pruning dates	PD-1	PD-2	P-Value	PD-1	PD-2	P-Value
Leaf Moisture content (%)	76.32	78.01*	0.025	71.79	76.33*	0.014
Moisture retention @ 6 hrs (%)	79.50	79.50	0.998	77.38	80.77*	0.006
Specific leaf area (cm^2 g^{-1} DW)	232.20	256.28	0.185	193.47	177.46*	0.001
Chlorophyll content index	13.57	14.96	0.095	14.73	15.49	0.105
Total chlorophyll content (mg g^{-1})	3.44	3.67	0.156	4.63	4.83	0.160
Total soluble protein (mg g^{-1})	29.81	31.65	0.134	31.09	31.75	0.238
Total soluble sugars (mg g^{-1})	29.94	32.73	0.079	31.73	34.17*	0.029
Leaf fall at harvest (%)	19.37	10.52*	0.002	1.22	15.21*	0.021
Fresh leaf weight (g)	2.021	1.999	0.645	2.454	2.894	0.050
Fresh leaf area (g)	110.83	109.56	0.854	110.26	143.00*	0.025
Leaves per meter shoot (No.)	23.47	23.63	0.742	15.44	18.83*	0.044
Length of longest shoot (cm)	91	104*	0.016	64	104*	0.001
Primary shoots $plant^{-1}$ (cm)	9.18	10.60*	0.000	13.93	12.93	0.185
Total shoots length $plant^{-1}$ (cm)	779	920*	0.007	659	1012*	0.014
Leaf yield $plant^{-1}$ (g)	256	287*	0.022	246	518*	0.000
Shoot yield $plant^{-1}$ (g)	492	497	0.691	381	860*	0.001
Leaf to shoot ratio (%)	52.08	57.69*	0.033	63.44	60.20	0.023
Leaf productivity (kg ha^{-1})	3156	3538*	0.022	3111	6489*	0.000
% yield advantage over existing date	-	12%	-	-	108%	-

(Note: PD1: Existing mulberry pruning date; PD2: New mulberry pruning date)



a) Leaf yield (kg ha^{-1}): Pruning date



b) Silkworm cocoon yield (kg): Rearing date

Figure 2: Performance of mulberry and silkworm crop schedule on leaf and cocoon yield

in new pruning schedule (Table 2). The new mulberry crop schedule was found to be effective in improvement nutritive quality and shoots growth resulted in double the leaf productivity in spring season 2020 (Figure 2). Similarly, higher yields were observed with increased length between harvests by Boschini (1995). The mulberry variety S-1635 recorded significantly higher leaf quality and yield due to alternate pruning date in autumn and spring seasons. The higher leaf yield in alternate pruning date due to more optimal temperature in autumn and delayed harvesting promoted better growth in spring season.

Mulberry Cocoon Yield and Silk Quality in Alternate Date of Silkworm Rearing

The generation of high-quality cocoons is the ultimate objective in sericulture and it largely depends on the quality of the mulberry leaf, the climate, and the methods used for rearing. Mulberry leaf quality suitable for healthy growth of silkworm depends on chemical constituents such as water (80%), protein (27%), carbohydrate (11%), minerals and vitamins along with favourable physical features (Rajan and Himantharaj, 2005). Mulberry crop duration and climatic factors during growth period will influence these parameters to a greater extent and in turn affects silk cocoon characteristics. The poor quality of leaf is one of the important factors attributed to the poor productivity of silk per unit area (Nagarajan and Radha, 1990). Optimal pruning time and sufficient crop duration ensures production of higher quality mulberry foliage per unit area. In the present study, silkworm rearing was performed with bivoltine hybrid (SK6 × SK7) on alternate rearing date in accordance with mulberry crop pruning during two commercial crop seasons. In the present study, mean performance of two silkworm rearing dates on cocoon yield and silk quality in different crops are given in table 3. The new silkworm crop schedules recorded significantly higher effective rearing rate by number than existing schedule during Agrahayani crop 2019. The new rearing schedule crop recorded higher mature larval weight (3.97 g), single cocoon weight (1.787 g), single shell weight (0.272 g), ERR (8,411 cocoons), non-breakable filament length (636 m), silk recovery (72.93%), silk reliability (76.93%) along with more than 90% neatness, cleanliness and evenness. Further, most of the silk reeling parameters are significantly higher in the new silkworm crop schedule (Table 3). The new rearing schedule was found to be effective in improvement cocoon productivity along with better silk quality due to more favorable environment. During Falguni crop, new silkworm rearing schedule recorded significantly higher mature larval weight (3.80 g), effective rearing rate (89%), non-breakable filament length (699 m), silk recovery (72%) and cocoon productivity (62 kg) (Table 3). However, single cocoon weight and single shell weight were higher under existing rearing date. The new rearing schedule was found to be effective in improvement of cocoon output (12%) along with silk quality during Falguni 2020 crop. The new rearing date ensured better mulberry growth and leaf quality which resulted in higher leaf and cocoon output. These results are in conformity with higher performance of breeds and hybrids in the spring (Feb-Mar) obtained by Chatterjee and Ray (2020). Hence, the optimal environment during alternate rearing schedule resulted in higher cocoon production along with silk quality.

Table 3: Mean performance of two silkworm rearing dates on cocoon yield and silk quality in different crops

Crops	Agrahayani 2019			Falguni 2020		
Cocoon Traits/ Rearing dates	RD-1	RD-2	P-Value	RD-1	RD-2	P-Value
Mature larval weight (g TL^{-1})	38.37	39.21	0.402	34.80	38.00*	0.018
Single Cocoon weight (g)	1.765	1.787	0.195	1.598*	1.423	0.023
Single Cocoon weight (g)	0.269	0.272	0.465	0.252	0.222	0.055
Shell weight ratio (g)	15.27	15.22	0.849	15.86	16.07	0.582
Effective rearing rate (No.)	7289	8411	0.254	7400	8900*	0.006
Effective rearing rate (kg)	13.72	15.13	0.047	11.52	13.42*	0.015
Filament length (m)	790	798*	0.000	765	699	0.000
Non-Breakable Filament length (m)	634	636	0.001	602	699*	0.000
Reliability of silk (%)	75.93	76.93*	0.000	72.41	71.93	0.000
Silk Recovery (%)	72.93	74.98*	0.000	71.02	71.93*	0.000
Denier (%)	2.71	2.75*	0.000	2.57	2.73*	0.000
Renditta (%)	8.96	8.72	0.000	8.20	8.63*	0.000
Neatness (%)	86.92	88.91*	0.000	88.91	87.91	0.000
Cleanliness (%)	88.91	90.91*	0.000	89.91	89.91	0.000
Evenness (%)	89.91	90.91*	0.000	87.91	88.91	0.000
Cocoon yield (kg 100 $DFLs^{-1}$)	68.61	75.67*	0.008	55.59	62.08*	0.015
% yield advantage over existing date	-	10%	-	-	12%	-

(Note: RD1: Existing silkworm rearing date; RD2: New silkworm rearing date)

Conclusion

Climate change has a negative impact on the yield of mulberry leaves and cocoons in the lower Gangetic region due to increased autumnal temperatures and a reduced spring growth time. Investigating potential adaptive strategies is therefore required to deal with these detrimental effects. Considering the findings of our study, it can be said that the new mulberry and silkworm crop schedules provide the best conditions, leading to increased leaf yield and cocoon output. According to the analysis, delaying mulberry pruning and silkworm rearing by two weeks will significantly lessen the effects of climate change. In response to the anticipated climate change, the revised mulberry sericulture crop schedules will be an adaptation strategy to maintain or improve production potential.

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