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Raw Silk Yield and Quality of Cocoons from Silkworms Reared Using Different Mulberry Production Practices

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Abstract

Enhancing silk yield and quality through diverse mulberry production practices is essential. This study assessed silkworm performance in terms of cocoon yield, raw silk quality, and production cost. Various mulberry leaf types, including Organic VAM (T_1), Organic VAMRI (T_2), Leisa VAM (T_3), LEISA VAMRI (T_4), and Conventional methods (T_5), were fed to silkworms, and their cocoons were reeled. Data were analyzed using the Randomized Complete Block Design (RCBD). Results showed comparable cocoon characteristics, reeling performance, and silk quality across different mulberry production practices, except for reelability percentage. Cocoons from silkworms fed with Organic Vam exhibited the highest reelability percentage (88.38% to 93.94%) and the lowest renditta (8.94 to 9.21 kg), resulting in lower reeling waste (36%). Profitability analysis indicated the highest gross income from cocoons reared under Organic Vam, totaling Php 13,740.00. Moreover, cocoons from Organic Vam production yielded the highest Net Income (NI) of Php 3,778.68 and a Return on Investment (ROI) of 37.93%. Among the various mulberry production practices, the use of Organic VAM can be the most effective for higher cocoon yields, superior raw silk quality, and greater economic returns in silkworm rearing and cocoon production.

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Introduction

Among the agricultural practices that lead to high productivity and sustainability are the use of diverse crops multiple cropping, nutrient cycling to minimize losses as composting, crop rotations (Shah *et al.*, 2021); use of farm-generated resources, enhancement of soil ability to store nutrients for future use and maintenance of protective soil cover, crop residue and living mulches (Clark, 2015).

Organic fertilizers comprise a variety of plant-derived materials that range from fresh or dried plant material to manure and litter to agricultural by-products (Wohlfarth and Schroeder, 1979; Das & Jana, 2003; Kumar *et al.*, 2004). The nutrient content of organic fertilizers varies greatly among source materials, and readily biodegradable materials make better nutrient sources (Green, 2015).

Manure derived from conventional livestock production systems is commonly used in agriculture to improve soil quality and as an organic fertilizer, to provide nitrogen enhancement and increase organic matter (Das *et al.*, 2017), as cited by Laconi, 2021. Microbial communities in manure may influence soil microbiome, either directly through competition or indirectly by spreading antimicrobial resistance (AMR). The extent to which the manure microbiome influences the soil microbial community remains unclear. Although some studies have found that organic manure application significantly alters the soil microbiome (Stocker *et al.*, 2015; Zang *et al.*, 2020) as cited by Lacomi 2021. After fertilization, antimicrobial residues may spread into the surrounding environment, potentially inducing the emergence of resistant bacteria and antimicrobial resistance genes (ARGs) Hou *et al.*, 2015; Munk *et al.*, 2018; Qiao *et al.*, 2018; Rovira *et al.*, 2019; Xia *et al.*, 2019a) as cited by Laconi *et al.*, 2021.

Organic matter in the soil acts as a reservoir for carbon, effectively capturing atmospheric carbon dioxide through the process of photosynthesis and incorporating it into the soil. Additionally, soil organic matter enhances soil fertility, water-holding capacity, and nutrient cycling, thereby supporting sustainable agriculture and ecosystem health (Rohith, 2023).

In sericulture, the application of the required nutrient in the required amount of mulberry trees is very essential for successful silkworm growth and cocoon production. This can be done through the utilization of fertilization strategies. Mulberry leaves, the sole food for silkworms play a vital role in the growth and development of silkworm larvae and turn silk production. Leaf quality and quantity not only influence larval growth and development but also the cocoon production (Kamel, 2014).

Silk reeling is a process in which filaments from cocoons are wound together to form a thread of silk. Filaments are collectively formed from a group of cooked cocoons from a warm water bath. Heat loosens the sericin in the cocoons to unwind the silk thread from the cocoons through moving reels. The demand for high-grade industrial silk yarn is high up to some extent currently unmet by supply. Determining the raw silk yield and quality of cocoons reared under different cropping practices would provide a competitive edge in producing quality raw silk.

The study aimed to help increase the productivity and profitability of raw silk especially the small growers by developing or adopting economically feasible cropping practices that are location-specific, using indigenous and environment-friendly resources that could produce quality cocoons, raw silk, and fabrics. It specifically aimed to (a) determine the quality of cocoons and raw silk from silkworms reared under different cropping practices; (b) determine the raw silk yield of cocoons reared under different cropping practices; and (c) determine the cost of producing raw silk from cocoons reared under different cropping practices.

Methodology

Treatments Used

DMMMSU 346 cocoons produced in different mulberry production practices were reeled and subjected to cocoon and raw silk assessment. The treatments used were: T_1= Organic-VAM (10 t/ha composted Silk waste + 10 t/ha *kakawate* fresh leaves + 5 kg VAM/ha biofertilizer); T_2= Organic-VAMri (10t/ha composted Silk waste + 10 t/ha *kakawate* fresh leaves + 5 kg VAMri/ha biofertilizer); T_3= LEISA - VAM (75-50-50 kg N, P_2O_5, K_2O, 5 t/ha Silk waste + 5 kg VAM/ha); T_4= LEISA – VAMri (75-50-50 kg N, P_2O_5, K_2O, 5 t/ha Silk waste + 5 kg VAMri/ha) and T_5: Conventional (150-50-50 kg N, P_2O_5, K_2O), which is the farmer's practice, as control.The treatments were laid in Randomized Complete Block Design (RCBD) with three replications. Analysis of Variance (ANOVA) in RCBD was used in the analysis of data and the Highest Significant Difference (HSD) was used in the treatment comparison.

Gathering of Data

The data gathered were grouped as follows: cocoon characters; reeling performance and raw silk quality. For cocoon characters, the following data gathered were: (a) *Filament Length* (m)- this was determined using the formula: total filament length or reeled silk (m)/Number of cocoon samples reeled; (b) *Denier/Filament Size* which is the unit that shows the size of the fiber and relation with regards to fiber length and weight and was determined using the formula: weight of reeled silk (g) /length of reeled silk (m) x 9,000. For reeling performance, the following data gathered were: (a) *Raw Silk Yield* which is the total weight of raw silk produced from the cocoons used in reeling and was determined using the formula: Weight of raw silk (kg)/ Weight of cocoons reeled (kg) X 100; (b) *Reelability Percentage* (%) *which* is the suitability of cocoons for economic reeling and was determined using the formula: Number of cocoons reeled/ Number of cocoons reeled + number of breaks x 100%; (c) *Renditta* is the ratio between the number of cocoons used in reeling and the actual quantity of raw silk obtained; (d) *Reeling Waste Percentage* which includes brushed silk, pupa and unreelable cocoons and was determined using the formula: Weight of silk waste (g)/ Weight of cocoons used during reeling (g) X 100%.

For Raw Silk Quality, the following data gathered were: (a) *Elongation* was determined by getting the difference between the length of a stretched specimen and its initial length expressed as a percentage of the initial length; (b) *Unevenness* (U %) was the variation of one specific property and linear density. This method is concerned with measuring the unevenness of a textile strand; (c) *Yarn number/Evenness test* was done to determine the degree of evenness of raw with approximately the same length of the sizing skein. Evenness defects are those positive of raw silk threads on an inspection board that show stripes caused by variations in the size of raw silk to such a degree as it is easily noticeable by visual inspections.

For the economic analysis, the following data were gathered: (a) *Gross Income*, which was determined by getting the Total Yarn Produced X Price; (b) *Net Income*, which was computed by getting the Gross Income less the Total Expenses (Fixed + Variable Cost); and (c) *Return on Investment (ROI),* was computed using the formula: Net Income/Total Expenses.

Results and discussion

Cocoon Characters

Filament Length

Table 1 presents the filament length of cocoons reared under different cropping practices. It can be observed that during Year 1, numerically shorter filaments of 545.17 to 672.40 m were produced. From Year 2, Year 3, Year 4, and Year 5, cocoons having longer filaments were produced and all the treatments were comparable with filament lengths of 712.94 to 793.33 m. This result reveals that using Organic and Leisa farming practices with biofertilizers VAM or VAMRI can be an alternative method to conventional farming. These practices are more sustainable in the long run and cheaper since the raw materials used are available on the farm. Significantly, a variation was observed in the silk filament length and cocoon reelability of cocoons due to the use of biofertilizers. Similarly, the reel ability of cocoon was also significantly increased. (Baqual & Das, 2006).

Table 1. Cocoon Filament length produced by silkworms reared under different mulberry production practices.

TREATMENT	SEASON/YEAR				
	Year 1	Year 2	Year 3	Year 4	Year 5
Organic + VAM biofertilizer	617.67abc	738.33a	726.20a	763.30a	782.10a
Organic + VAMri biofertilizer	672.40a	734.20a	793.23a	783.90a	784.57a
Leisa + VAM biofertilizer	660.83ab	712.94a	726.60a	713.93a	743.16a
Leisa + VAMri biofertilizer	584.76bc	780.37a	743.20a	755.76a	769.93a
Conventional (Inorganic fert)	545.17c	742.10a	748.56a	784.57a	765.30a
Level of Significance **significant*	*	*	*	*	*
c.v. (%)	4.83				

Filament Size/Denier

The fineness of silk fibers is expressed in terms of denier (mass of 9 km fiber expressed in grams). The silk filament size of cocoons of bivoltine silkworms averages at 2.0 to 3.0 grams (Padaki *et al*., 2015). It can be noted that in all the treatments that were reared from Year 1 to Year 5, the denier size or filament of the cocoons were comparable and no significant difference was observed. Leisa + VAM cocoons reared during Year 4 had a denier size of 3.24 while the thinnest filament was recorded in the cocoons of Organic VAM, Organic VAMRI, and Leisa VAMRI that were reared in Year 1 of 2.19, 2.28, and 2.33 (Table 2).

Table 2. Denier size of cocoons reared under different cropping practices.

TREATMENT	SEASON/YEAR				
	Year 1	Year 2	Year 3	Year 4	Year 5
Organic + VAM biofertilizer	2.19	2.84	3.0	2.85	3.01
Organic + VAMri biofertilizer	2.28	2.91	2.83	2.83	2.96
Leisa + VAM biofertilizer	2.44	2.79	3.00	3.24	2.84
Leisa + VAMri biofertilizer	2.33	2.69	3.03	3.06	2.99
Conventional (Inorganic fert)	2.52	2.67	2.91	2.68	2.86
Level of Significance	ns	ns	ns	ns	ns
c.v. (%)	6.78				

Table 3. Reelability percentage of cocoons reared under different cropping practices. Where is the difference.

TREATMENT	SEASON/YEAR				
	Year 1	Year 2	Year 3	Year 4	Year 5
Organic + VAM biofertilizer	88.38	88.38	88.38	88.38	93.84
Organic + VAMri biofertilzer	88.38	81.21	93.94	90.91	88.38
Leisa + VAM biofertilizer	90.91	88.38	88.38	90.91	88.38
Leisa+ VAMri biofertilizer	88.38	83.33	93.94	88.38	88.55
Conventional (Inorganic fertilizer)	85.96	79.06	90.91	85.86	85.86
Level of Significance	ns	ns	ns	ns	ns
c.v. (%)	4.57				

Based on the above results, cocoons reared under the different cropping practices met the normal standards in terms of denier/filament size.

Reeling Performance

Reelability Percentage

Table 3 presents the reelability percentage of cocoons reared under different cropping practices. It can be observed in the table that there were no significant differences among the treatments. The reelability percentage ranged from 83.33% to 93.94%.

Organic VAMRI cocoons and conventional cocoons in Year 2 (2016) produced the lowest reelabilty percentage of 81.21 and 79.06%. Environmental conditions such as high relative humidity (85%) is constant temperature and air current during the spinning of cocoons are effective (Boraiah, 1986).

Raw Silk Yield

Table 4 presents the raw silk yield of the cocoons reared under different cropping practices. It can be noted that the raw silk yield of all the treatments revealed significant differences. This implies that the new technologies can be alternative fertilization strategies for mulberry cultivation. Recycling silk wastes into compost reduces waste build-up in the locality, thus, avoiding air pollution. Likewise, the use of *kakawate* leaves as green leaf manure could first serve as mulch that when eventually composted becomes a good source of fertilizer.

Table 4. Raw silk yield of cocoons of cocoons reared under different cropping practices.

TREATMENT	SEASON/YEAR				
	Year 1	Year 2	Year 3	Year 4	Year 5
Organic + VAM biofertilizer	26.33a	28.67a	27.67a	28.00a	27.33a
Organic +VAMri biofertilizer	26.33a	25.00a	25.00a	26.67a	26.33a
Leisa + VAM biofertilizer	26.33a	25.00a	26.33a	26.33a	25.67a
Leisa + VAMri biofertilizer	25.00ab	26.33a	22.67b	27.00a	24.67ab
Conventional (Inorganic fert)	24.33c	24.00c	28.00a	27.67ab	25.33bc
Level of Significance **significant*	*	*	*	*	*
c.v. (%)	5.66				

Renditta

Table 5 presents the renditta of cocoons reared under different cropping practices. Renditta refers to the weight of fresh cocoons to produce a kilogram of raw silk. It can be observed in the table that the renditta of all treatments reared from Year 1 to Year 5 registered significant differences. Cocoons of Organic Vam registered the lowest renditta of 9.21 kg. Renditta is the most important point for consideration for a reeler because it has a direct connection with the price to be paid for cocoons and the cost of production of raw silk (Manual in Sericulture, 1987).

This result implies that the new farming practices, using Leisa and Organic Farming + biofertilizers performed at par with conventional farming practices and hence could be an alternative soil management option in mulberry cultivation.

Table 5. Renditta of cocoons reared under different cropping practices.

TREATMENT	SEASON/YEAR				
	Year 1	Year 2	Year 3	Year 4	Year 5
Organic + Vam biofertilizer	8.96	8.96	9.96	8.94	9.21
Organic + Vamri biofertilizer	9.50	13.07	9.15	9.37	9.35
Leisa + Vam biofertilizer	9.72	10.00	9.52	9.53	9.65
Leisa+ Vamri biofertilizer	10.00	9.46	10.24	9.33	9.61
Conventional (Inorganic fert)	10.41	10.36	8.40	9.13	10.13
Level of Significance **significant*	ns	ns	ns	ns	ns
c.v. (%)	11.68				

Table 6 presents the reeling waste percentage of cocoons reared under different cropping practices. As shown in the table reeling waste percentage was significantly influenced by the different cropping practices. Organic Vam cocoons produced the lowest reeling waste percentage compared to the other cropping practices.

Raw Silk Quality

Table 7 presents the raw silk quality of the cocoons reared under different cropping practices. The elongation of the raw silk of the cocoons ranged from 14.73 to 15.70%. All the Treatments showed comparable results and no significant difference was observed.

Table 6. Reeling waste percentage of cocoons reared under different cropping practices.

TREATMENT	SEASON/YEAR				
	2015	2016	2017	2018	2019
Organic Vam	0.3600	0.3600	0.3800	0.3300	0.3667
Organic Vamri	0.3533	0.3800	0.3800	0.3400	0.3667
Leisa Vam	0.3800	0.3700	0.3800	0.3400	0.3800
Leisa Vamri	0.3700	0.4000	0.3600	0.3100	0.3833
Conventional (Inorganic fert)	0.3733	0.3800	0.4000	0.3400	0.3833
Level of Significance *significant	ns	ns	ns	ns	ns
c.v. (%)	6.22				

Evenness

With regards to the evenness test of the raw silk of the cocoons reared under the different cropping practices, Organic Vamri registered the highest evenness test of 14.01% followed by Organic Vamri of 10.84%. The lowest evenness test was produced by Conventional, Leisa Vamri and Leisa Vam of 7.63, 6.49 and 6.44%. The highest yarn number was obtained by Conventional of 39.38 denier but was comparable to the other treatments and no significant differences were observed. The raw silk quality of cocoons as to elongation (%), unevenness (%), and yarn number were not significantly influenced by the different cropping practices. This means that the use of new practices could be done instead of conventional practices.

Table 7. Raw silk quality of the cocoons reared under different cropping practices.

TREATMENT	RAW SILK QUALITY		
	Elongation (%)	Unevenness, U (%)	Yarn Number/ Evenness test (d)
Organic Vam	15.52	14.01	34.08
Organic Vamri	15.56	10.84	35.58
Leisa Vam	14.73	6.44	33.78
Leisa Vamri	15.59	6.49	35.16
Conventional	15.70	7.63	39.38
Level of Significance	ns	ns	ns
c.v. (%)	12.11	15.15	20.40

Economic Analysis

Table 8 presents the Gross, Net Income, and ROI reared under different cropping practices. The table reveals that raw silk produced from the cocoons reared using Organic + VAM biofertilizer recorded the highest gross income of ₱ 13,740.00. Hence, a net income of P 3,778.66 was derived with an ROI OF 37.93%. These initial findings imply that the cocoons reared under the different cropping practices using Organic+ VAM biofertilizer (10t silk waste +5kg VAM ha^{-1}) produce higher raw silk yield.

Table 8. Gross Income, Net Income and ROI raw silk reared under different cropping practices.

TREATMENT	Gross Income (₱)	Expenses (₱)	Net Income (₱)	ROI (%)
Organic Vam	13,740.00	9,961.34	3,778.68	37.93
Organic Vamri	12,514.00	9,961.34	2,553.06	25.63
Leisa Vam	12,754.40	9,961.34	2,793.06	28.03
Leisa Vamri	12,760.04	9,961.34	2,798.70	28.09
Conventional	12,226.20	9,961.34	2,264.86	22.73

This was followed by Leisa + VAMRI biofertilizer with a gross of ₱ 12,760.04, Net Income of ₱ 2,798.70 with an ROI of 28.09%, Leisa + VAM biofertilizer with a gross income of ₱ 12,754.40, net income of 2,793.06 with an ROI of 28.03%, Organic + VAMRI with a gross income of ₱ 12,514.40, net income of ₱ 2,553.06 with an ROI of 25.63% and Conventional with a gross income of ₱ 12,226.20, net income of ₱ 2,264.86 with an ROI of 22.73%.

Conclusion

Based on the result of the study of cocoon characters, shorter filament length was observed during Year 1. From Year 2 to Year 5, longer filament lengths were produced in all the treatments. Further, a thinner denier size was observed in Year 1. The thickest filament size was recorded from the cocoons of Organic VAM and Organic VAMRI during Year 2; Organic VAM, Leisa VAM, and Leisa VAMRI during Year 3; Leisa VAMRI in Year 4; and Organic VAM in Year 5.

Results of the study also indicated that the farming practices employed had similar effects on the reeling performance and raw silk quality except for reelability percentage where Organic VAM had the highest percentage ranging from 88.38 to 94% from Year 1 to Year 5. Organic VAM also obtained the lowest renditta of 8.94 to 9.21 kg, thus lesser reeling waste was noted (33%). Recorded results on the raw silk quality as to the elongation ranged from 14.73 to 15.70%. With regards to the evenness test of the raw silk produced from cocoons reared under the different cropping practices, Organic VAM registered the highest evenness percentage of 14.01%. The highest yarn number was obtained by conventional cropping of 39.38 denier. With regards to Net Income and Return on Investment, the highest net income was recorded in cocoon reared under Organic VAM, followed by Leisa VAMRI, Leisa VAM, and Organic VAMRI. The lowest was observed in conventional practices.

Recommendation

With the foregoing results, the use of various organic farm practices in mulberry leaf production, particularly Organic VAM can be recommended for higher cocoon yield, superior silk quality and higher economic returns.

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