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Mulberry (*Morus alba* L.) farming systems: Impact on silkworm growth and cocoon production in northern Philippines

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Abstract

Sustainable farming practices using LEISA and Organic Farming combined with biofertilizers were evaluated to improve sericulture farm productivity and profitability of sericulture farms in Northern Philippines. Growth and yield parameters for silkworms were gathered; tabulated and analyzed using Combined ANOVA (RCBD) and means were compared using HSD. Cost-returns was also estimated. Three systems were found productive: LEISA + biofertilizer 2, Biofertilizer 1, and Organic + Biofertilizer 2 as indicated by heavier 10 mature larvae, higher effective rearing rates and consequently higher cocoon yield per box. Rearing seasons significantly affected the silkworm growth, yield and cocoon characters. The best seasons were during the colder months, November-December (Year 1), May-June (Year 2) and September-October (Year 2). The weight of 10 matured larvae, effective rearing rates, and cocoon yield per box were significantly influenced by the farming systems at each level of rearing seasons. Higher net income and return on investment (main and combined products) were recorded in LEISA + Biofertilizer 1 and Biofertilizer 2, Organic farming + Biofertilizer 1 and Biofertilizer 2 compared with cocoons raised in conventional practices.

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Introduction

Sericulture in the Philippines should be rigorously pursued to meet local and international demands for silk fabrics and other allied products. With the strong support of government agencies and funding support of international institutions, sericulture is one of the agro-based industries that could boast economic growth for farmers owing to still vast land to cultivate suitable climate and available manpower and resources to perform enormous activities in both agricultural and industrial phase of the industry. International institutions (Japanese govt), also provide funds/grant to promote sericulture production in the Philippines (Mabesa, 2019).

Despite these potentials, silk production is low to meet local demands. Sericulture in Region I is conventionally farmed using inorganic fertilizers, pesticides and fossil fuel for irrigation among others. With increasing inflation rates and soaring prices of the inputs and labor, farmers can no longer apply the needed requirements of mulberry plants for plant growth and development. In CY 2022, extension reports revealed low farm productivity and profitability due to low quality mulberry leaf and cocoon yield because of the presence of weeds, low soil fertility, limited water supply and high pest and disease incidence (SRDI Annual Report, 2022).

To improve farm production and income, measures should be in line with the Sustainable Development Goals of the of the United Nations, to end poverty and hunger, achieve food security and improved nutrition and promote sustainable agriculture, promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all, among others. To achieve these, new farming systems were designed and employed using the Low External Input Sustainable Agriculture (LEISA) and organic farming in place of the conventional farming practices. The LEISA techniques involved the use of sustainable technologies such as waste recycling (composting), biofertilization, and use of green manures instead of chemical fertilizers. This was to avoid if not eliminate the adverse effect of continuous use of chemical fertilizer on the soil, human and environment.

The application of plant nutrients through recycling of sericulture farm wastes as composts, vermi-composts and balance use of chemical fertilizers can facilitate quality leaf production for a better and sustainable silkworm cocoon production due to the presence of major and minor plant nutrients. Silk wastes composed of silk litters and leaf scraps when composted and applied into the soil are good sources of fertilizer. The application of reduced doses of nitrogen and phosphorus supplemented by various types of organic manures attributed cocoon yield and other economic characters of rearing and reeling at par with the control.

Hence, the package comprises of *Arbuscular mycorrhiza* (AM) fungi-inoculated saplings variety S-1, green manuring with *Crotalaria juncea* during rainy season and leguminous cover crop with *Ligna umbellata* during winter season along with the application of 50% reduced doses of N and P and full dose of K may be recommended for quality leaf yield, successful silkworm rearing and lower expenditure in mulberry cultivation under rainfed alluvial soil conditions (Saha *et al.*, 2006).

In organic farming, composting of sericulture wastes has been advocated by many workers to prevent the spread of silkworm diseases including Pebrine, Nuclear Polyhedrosis Virus (NPV) and Cytoplasmic Polyhedrosis Virus (CPV). It has been known that Pebrine spores become inactive at temperatures 55 to 60^{o}C (Das *et al.*, 1990). On the other hand, biofertilizers sustain soil fertility resulting in increased crop yield without causing any environmental, water or soil hazards. VAM fungi in association with higher plants play an important role in phosphorus nutrition and increase plant growth and yield, similarly to VAM and PSM, the *Phosphobacterium*. When applied to the soil, it solubilizes the insoluble phosphorus in the soil to make it available to the plants for absorption (Dayakar, 2011).

Although these practices seemed promising in improving farm productivity, the right combinations of chemical fertilizers along with organic fertilizers must be determined to create balance fertilization mixtures that could enhance the growth and development of mulberry plants at minimum cost. Hence, this study that aimed to determine the silkworm growth, and cocoon yield and quality when fed with leaves grown using different farming practices in different rearing seasons. It also determined the cost-returns of producing cocoons in different farming systems.

Materials and methods

The study was conducted at the rearing house of the DMMMSU-SRDI Grainage Building in Brgy. Sapilang, Bacnotan, La Union, Philippines. The study utilized the plantation set up of the research study on farm waste utilization in different farming practices of the Institute.

Bioassay test

Leaves from the different farming system practices were gathered and used in the bio-assay test as follows:

A-Leaves from Conventional Farming Practices (150-50-50 kg N, P_2O_5, K_2o)

B-Leaves from LEISA–Biofertilizer 1 (VAM) (75-50-50 kg N, P_2O_5, K_2o, + 5 t silk wastes + 5 kg VAM/ha)

C-Leaves from LEISA–Biofertilizer 2 (VAMri) (75-50-50 kg N, P_2O_5, K_2o, 5 t silk wastes compost + 5 kg VAmri/ha)

D-Leaves from Organic Farming Practices–Biofertilizer 1 (VAM) (10 t silk wastes compost + 10 t kakawate leaves + 5 kg VAM/ha)

E-Leaves from Organic Farming practices–Biofertilizer 2 (VAMri) (10 t silk wastes compost + 10 t kakawate leaves +5 kg VAMri/ha)

Preparation of the rearing house and implements

The rearing house including the rearing implements such as rearing racks, rearing trays, leaf chamber, and plastic mountages were disinfected and sprayed with disinfectants three days before rearing. Other materials like paraffin papers, chicken feather, bedding and cleaning nets, silkworm bed disinfectants, and burnt rice hull were also prepared. Leaves from the different treatments were harvested in the research area (whole leaves), placed in cheese cloth bags then preserved in a leaf chamber lined with wet cloth.

Silkworm rearing

The silkworm larvae were brushed in a tray lined with paraffin paper using a chicken feather. The young worms were fed with chopped leaves at desired sizes for four times daily (4:00 AM; 10:00 AM, 3:00 PM and 8:00 PM) for 12 days. Proper spacing was observed before feeding the worms. Monitoring of disease occurrence was done where diseased worms were removed then properly discarded.

At 3^{rd} instar- 2^{nd} day, 300 silkworms were counted to represent each treatment. At 4^{th} instar, whole leaves were fed to older worms (4^{th}-5^{th} instar larvae) for four times a day. In every instar, silkworms undergo moulting where feeding is stopped for 24-36 hours. During moulting, burnt rice hull is spread over the worms to hasten moulting. After moulting and the worms are about to resume feeding, the worms were disinfected with silkworm disinfectant. The beds were cleaned then the silkworms were transferred into new rearing trays lined with newspaper until they mature. The mature worms were then mounted into plastic mountages according to the treatments. The cocoons were harvested five (5) days after mounting.

Data gathering

The data gathered were as follows:

Effective rearing rate (ERR, %): The final percentage survival was recorded at harvesting period.

Effective rearing rate (%) = (No of cocoons that produced cocoon/ No of worms reared at third instar) × 100

Weight of 10 Matured Larvae (WTML g): 10 matured silkworms were randomly selected, weighed and recorded.

Single cocoon weight (SCW, g): 10 randomly selected cocoons were weighed and recorded.

Single shell weight (SSW, g): 10 randomly selected cocoons were cut to separate the shells then weighed.

Cocoon yield per box (CYB^{-1}, kg): Computed as 20,000 worms × Effective rearing rate (ERR) × Single cocoon weight (SCW)

Cocoon shell percentage (CSP, %): 10 cocoons were randomly selected and cut with a blade to separate the cocoons from the pupae. This was computed as:

CSP (%) = (Cocoon shell weight/ Cocoon Weight) × 100

The treatments were laid out in Randomized Complete Block Design (RCBD) with three (3) replications. The data were recorded, tabulated, consolidated and statistically analyzed. Analysis of variance (ANOVA) in RCBD in combined analysis was used in the analysis of data using the STAR software. HSD was used in treatment comparison.

All inputs and outputs were monitored and recorded in all operations from mulberry production to silkworm rearing to obtain a reliable cost-return analysis particularly on the different fertilizer treatments. Productivity and profitability were measured as follows:

Net returns (PHP) = Gross income – Total expenses

Return on investment (%) = (Net returns/Total production cost) × 100%

Gross return was computed as production (cocoon yields) multiplied by the current price of cocoons (PHP 200.00 per kg). Total expenses included variable cost (supplies and materials and the labor cost incurred in mulberry and silkworm rearing) and the fixed cost (depreciation cost, light and water expenses). Cost of materials and labor were based on the prevailing average prices during the cropping years. Total investment included the total production cost incurred in the production systems. The data were recorded, tabulated, consolidated and subjected to cost return analysis.

Results and discussion

Silkworm growth, yield and quality of cocoons produced using leaves grown in different farming systems and rearing seasons.

Weight of 10 matured larvae

The effects of the different farming systems and rearing seasons on the weight of 10 matured larvae are reflected in Table 1.

Effect of farming systems on the weight of 10 matured larvae

Heavier matured larvae were recorded in LEISA + Biofertilizer 2, but comparable to cocoons raised in LEISA biofertilizer 1 and Organic Biofertilizer 1. The lightest larvae was produced in conventional practice but comparable to Organic + Biofertilizer 2 and LEISA Biofertilizer 1. This result implies that a combined use of Organic and Inorganic fertilizer + Biofertilizer VAM or Vamri and using Organic fertilizer silk wastes and green leaf manure + Biofertilizer 1 effectively improved the growth of silkworm larvae. The use of LEISA Biofertilizer 1 and Organic Biofertilizer 2 were as effective as the conventional practice in improving silkworm growth. This could be due to the combined effects of the practices that led to better silkworm growth.

A biofertilizer is a substance which contains living microorganisms which, when applied to seed, plant surfaces or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the plant. The benefit of mycorrhizae to plants is mainly attributed to increased uptake of nutrients, especially phosphorus while in exchange of sugars provided by the plants. they absorb more nutrients and mobilize quickly to the plants than the root system does not have VAM association (Sakhivel *et al.*, 2014). Both organically and conventionally produced mulberry leaves contained moisture on top and bottom that are within the acceptable range for feeding young worms that is 78-80% for the 1st and 2nd instar, 76-77% for the 3rd instar, and 70% for mature worms (Caccam *et al.*, 2015). Moisture retention capacity of the leaves was still good even after 24 hours of storage. This implies that mulberry leaves could be stored for 24 hours without impairing the quality of leaves, particularly moisture. Data show that percent moisture, ash and crude fat in top to bottom portions of leaves in organic farming are slightly higher than in conventional farming. On the other hand, percent crude fiber and crude protein were slightly higher in conventional farming than in organic farming (Caccam *et al.*, 2015).

In a study conducted by Tangamalar *et al.* (2018), the application of 50% Organic + 50% Inorganic fertilizer showed significantly better mulberry growth and yield parameters and consequently higher economic parameters viz. larval weight, cocoon weight, shell weight, shell ratio and effective rearing rates in both kharif and rabi seasons.

Effect of rearing season on the weight of 10 matured larvae

Heavier matured larvae were recorded in silkworms raised in the August-September (Year 1); November-December (Year 2); and May-June and September-October (Year 3). The lightest was recorded during the May-June (Year 1) rearing season. The colder season that starts from the onset of rainy seasons (May to December) favored the growth of silkworms). At this season, the minimum temperature for young age was 25.99 ˚C, and the maximum was 28.08˚C with a relative humidity of 82.09%. For the late age, the minimum was 26.39˚C and the maximum was 27.87 ˚C with a relative humidity of 27.87%. It was evident that the lightest matured larva was observed during May to June rearing season (Year 1) as a consequence of a higher temperature during the year. The temperatures for young age ranged from 26.27 to 28.89˚C with an RH of 75.91%; while for late age, temperature ranged from 26.19-27.96˚C with an RH of 84.44%. Notably, these were higher than the required temperature for late age rearing.

Table 1. Weight of 10 mature larvae (g) of silkworms fed with leaves in different farming systems and seasons of rearing

Rearing season	Conventional	LEISA+ Biof. 1	LEISA + Biof. 2	Organic +Biof. 1	Organic +Biof. 2	Season mean
Nov.24-Dec.21, 2014	26.46a-c	27.12bc	29.57a	26.45bc	25d-f	26.92b
March 4-31, 2015	23.78cd	24.45cd	25.92b	24.05cd	21.62f	23.97c
Sept. 29-Oct. 28, 2015	26.46a-c	25.4bc	29.58a	26.45bc	25.00d-f	26.92b
May 10- June 6, 2016	22.10d	22.65d	21.06c	21.10d	22.78ef	21.94d
Aug 30-Sept 28 2016	29.39ab	28.15ab	29.78a	29.98ab	28.95ab	29.05a
June 30-July 22,2017	26.11bc	26.45bc	27.92ab	26.38bc	25.29c-e	26.43b
Nov.15-Dec. 23, 2017	28.23ab	29.37ab	29.47a	30.53a	27.03b-d	28.93a
May 22- June 12, 2018	29.72a	28.88ab	28.59ab	28.98ab	31.25a	29.48a
Sept. 27-Oct. 27, 2018	28.64ab	31.42a	28.51ab	30.13a	28.51a-c	29.44a
Treatment Mean	26.77b	27.09ab	27.82a	27.22a	27.00b	

In a column (season means at each level of seasons), row means (treatment means) followed by the same letter are not significantly different from each other at .05 levels HSD.

Comparison on treatment at each level of rearing season

Analysis of variance revealed significant differences on the WTML in different rearing seasons (Table 1, Fig. 1). The WTML in conventional treatment was comparable during the rearing months of May-June and Sept-Oct (Year 5), November-December (Year 4), August-September (Year 3), September-October (Year 2) and November-December (Year 1); in LEISA + Biofertilizer 1 during the months of May-June and September-October (Year 5), November-December (Year 4), August-September (Year 3); in LEISA + Biofertilizer 2 during the months of May-June and September-October (Year 5), November-December (Year 4), August-September (Year 3), September-October (Year 2) and November-December (Year 1); in Organic Farming + biofertilizer 1 during the months of May-June and September-October (Year 5), November-December (Year 4), August-September Year 3) and Organic farming + Biofertilizer 2, during the months of May-June and September-October (Year 5), and August-September (Year 3).

The results imply that the different farming systems responded differently with the different rearing seasons. However, regardless of farming systems, the best rearing seasons recorded were the months of August – September (Year 3), May-June (Year 5) and September-October (Year 5). These were the colder months of the year which favored the growth of the silkworms.

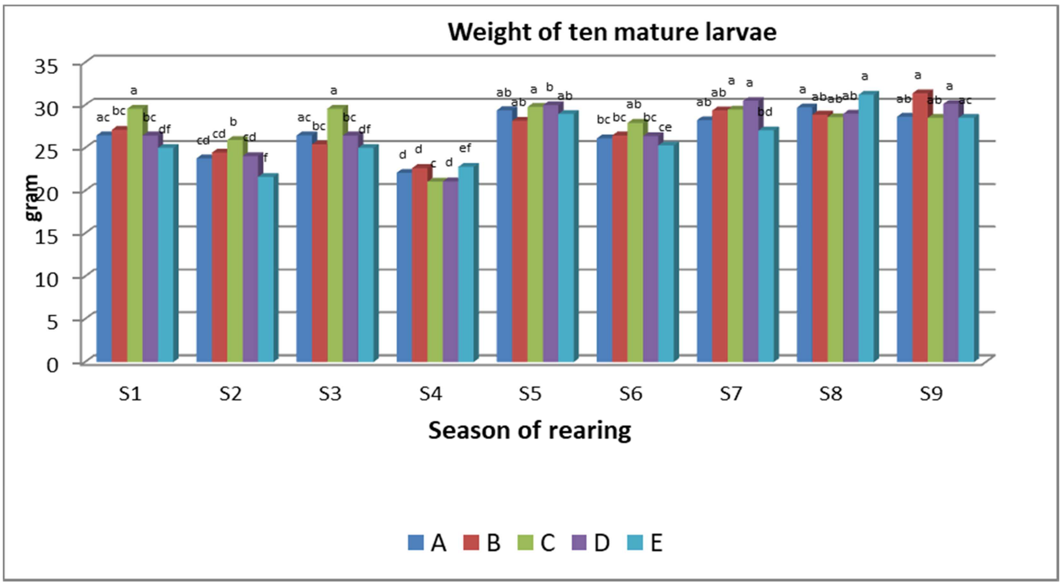

Fig. 1. Weight of ten mature larvae (g) of silkworms fed with leaves in plants grown in different farming systems at each level of seasons of rearing

Cropping systems: A- Conventional, B- LEISA + Bio-fertilizer 1, C- LEISA + Bio-fertilizer 2, D- Organic farming + Biofertilizer 1, E- Organic farming + Biofertilizer 2. Seasons of rearing: S1 Nov.24-Dec.21, 2014; S2 March 4-31, 2015; S3 Sept. 29-Oct. 28, 2015; S4 May 10- June 6, 2016; S5 Aug 30-Sept 28 2016; S6 June 30-July 22, 2017; S7 Nov.15-Dec. 23, 2017; S8 May 22- June 12, 2018; S9 Sept. 27-Oct. 27, 2018

Effective rearing rate

Effect of farming systems

Effective rearing rates were significantly higher in LEISA + Biofertilizer1 and Organic Farming + Biofertilizer 2 compared to other farming systems. The lowest was observed in conventional farming but comparable to LEISA + Biofertilizer 1 and Organic Farming + Biofertilizer 1 and 2. This implies that the use of combined chemical plus organic wastes and biofertilizer and use of organic fertilizers with biofertilizers alone is effective in enhancing the survival of silkworms. Philomena *et al.* (2003) and Tangamalar *et al.* (2018) have observed higher ERR in silkworms fed with mulberry leaves grown with lower dose of inorganic fertilizer and higher doze of organic manure. This could be an attributed to a better quality of leaves in these systems (Caccam and Mendoza, 2015). The success of sericulture industry is mainly based on leaf quality and appropriate environmental conditions for silkworm rearing (Kumar *et al.*, 2013). The effects of fertilizer management practices on leaf yield and quality of mulberry plant are important for sustainable mulberry plant production (Sultana *et al.*, 2017). Mulberry leaves are the exclusive source of nutrition (e.g., protein, carbohydrates, vitamins, minerals, etc.) for growth and development of silkworms (Tang *et al.*, 2005; Kumar *et al.*, 2013). The quality of leaves fed to silkworm is considered to be the prime factor for good cocoon production (Ravikumar, 1988).

Effect of rearing season

The silkworms reared during the November-December (Year 4), May-June (Year 5) and September-October (Year 5) rearing season significantly had higher ERR. During these seasons, the temperature range for young age was 25.33-27.71˚C with an RH of 79.75%. For late age, the temperature range was 25.79 to 27.85˚C and RH was 82.39%. These results corroborates with the findings of Madrid (2010) that the growth of silkworms are affected by season. December was the most favorable month for silkworm rearing which resulted to higher ERR (90.95%), and heavier silkworms (43.17 g). September rearing followed for most of the parameters except for filament length and size which were comparable to December. The crop was generally successful and the ERRs 70-80% and above indicate high yields. The lowest was observed in silkworms raised during the months of May (Year 2), May-June (Year 3), and June-July (Year 4). During these seasons, the average temperature for young age was 25.84-28.88ºC and an RH of 73.96% while for late age, the average temperature was 25.96-28.74˚C and an RH of 76.83%. According to Pawar *et al.* (2016) and Caccam *et al.* (2018), the variations within the environmental conditions day to day and season to season emphasize the necessity of management of temperature and relative humidity for sustainable production. In this study, day to day fluctuations went as high as 26-31˚C (10AM) and a RH of 60-72% and 26-33˚C (3 PM) and an RH of 54-80 % and during the May (Year 2), 26-31˚C and RH of 71-88% (AM) and 26-32.1˚C and RH of 30-86% (PM) during May-June (Year 3), and temperature of 26-30˚C and RH of 75-84% (AM) and temperature of 24-31˚C and RH of 72-84% (PM) during the June-July (Year 4) rearing season. In summer days, as temperature was very high, the silkworm could produce cocoons properly. Temperature above 30ºC directly affects the health of the worms. If the temperature is below 20˚C all the physiological activities are retarded, especially in early instar. As a result, worms become too weak and susceptible to various diseases. The optimum temperature for normal growth of silkworms is between 20˚C and 28˚C and the desirable temperature for maximum productivity ranges from 23˚C and 28˚C (Pawar *et al.*, 2016; Caccajm *et al.*, 2024).

Comparison of treatment at each level of seasons

The effective rearing rates of silkworm were significantly influenced by the farming systems and rearing seasons. The conventional treatment had comparable effective rearing rate during the months of Nov-Dec 2014, March 2015, Nov-Dec 2017, May-June and Sept-Oct 2018. In LEISA + bio-fertilizer 1 treatment, comparable ERR were observed during the Nov-Dec 2014, Sept-Oct 2015, Nov-Dec 2017, May-June and Sept-Oct 2018 rearing seasons while in LEISA + biofertilizer 2, it was comparable during Nov-Dec 2014, Sept-Oct 2015, May-June 2016, Aug-Sept 2016, Nov-Dec 2017, May-June 2018, Sept-Oct 2018 rearing seasons. In Organic farming + biofertilizer 1 and 2 treatments, the rearing seasons of Nov-Dec 2014, Sept-Oct 2015, May-June 2016, Nov-Dec 2017, May-June 2018, Sept-Oct 2018 that were comparable with each other were found better seasons than other rearing seasons (Table 2, Fig. 2). The result implies that the silkworms raised in different farming systems responded differently with the growing seasons. It could be noted that the best seasons for increasing survival of silkworms were the colder months of Nov–Dec 2017, May-June 2018, Sept–Oct 2018. For cocoons, ERR should be greater than 85 % for bivoltine races (Rajan *et al.*, 2005 as cited by Caccam *et al.*, 2024).

Single cocoon weight

Effect of farming systems

The single cocoon weight of silkworms fed with leaves grown in different farming systems that ranged from 1.42 to 1.44 g was not significantly different with each other (Table 3).

Table 2. Effective rearing rate of silkworms fed with leaves grown in different farming systems and seasons of rearing

Rearing season	Conventional	LEISA+ Biof. 1	LEISA + Biof. 2	Organic +Biof. 1	Organic +Biof. 2	Season mean
Nov.24-Dec.21, 2014	83.00ab	76.00ab	76.33a-c	82.00ab	88.00ab	81.07bc
March 4-31, 2015	71.00a-c	60.67bc	55.33c	47.33d	63.00c-e	59.47d
Sept. 29-Oct. 28, 2015	69.67bc	78.67ab	76.33ac	78.67ab	84.67ac	77.60c
May 10- June 6, 2016	32.00d	50c	78.67ab	47.33e	48c	51.20d
Aug 30-Sept 28 2016	69.67bc	80.33ab	83.33ab	72.33bc	72.33b-d	75.60 c
June 30-July 22,2017	57.67c	44.67c	67.33bc	53cd	58.33de	56.40cd
Nov.15-Dec. 23, 2017	92.33a	98a	98.33a	97.67a	95a	96.2a
May 22- June 12, 2018	93.00a	94.33a	95.67a	94.00ab	86.67ab	92.73a
Sept.27-Oct. 27, 2018	88.67ab	93.00a	96.67a	96.67a	92.33a	93.47a
Treatment mean	73.01b	75.07b	80.88a	74.33b	76.48ab	

In a column (season means at each level of seasons), row means (treatment means) followed by the same letter are not significantly different from each other at .05 levels HSD.

Table 3. Single cocoon weight (g) of cocoons of silkworms fed with leaves in different farming systems and seasons of rearing

Rearing season	Conventional	LEISA+ Biof. 1	LEISA + Biof. 2	Organic +Biof. 1	Organic +Biof. 2	Season mean
Nov.24-Dec.21, 2014	1.38	1.50	1.47	1.45	1.51	1.46c
March 4-31, 2015	1.36	1.30	1.30	1.39	1.28	1.32d
Sept. 29-Oct. 28, 2015	1.31	1.30	1.37	1.33	1.48	1.36d
May 10- June 6, 2016	1.06	1.08	1.11	0.93	1.08	1.05e
Aug 30-Sept 28, 2016	1.54	1.54	1.60	1.57	1.55	1.56b
June 30-July 22, 2017	1.68	1.70	1.71	1.76	1.68	1.71a
Nov.15-Dec. 23, 2017	1.61	1.69	1.65	1.54	1.60	1.62b
May 22- June 12, 2018	1.52	1.52	1.55	1.54	1.59	1.54bc
Sept. 27-Oct. 27, 2018	1.55	1.57	1.54	1.54	1.51	1.54bc
Treatment mean	1.42	1.44	1.46	1.42	1.45	
	1.45	1.46	1.48	1.45	1.47	

In a column (season means), means followed by the same letter are not significantly different from each other at .05 level HSD

The result implies that the newly introduced farming systems did not pose any negative effects to the cocoons as it performed at par with the traditional conventional farming. Though the single cocoon weights in different farming systems felt short of the standard single cocoon weight for high production due to low cocoon yield and quality during Nov-Dec 2014 to May-June 2016 seasons very evident that on later years (Aug-Dec 2016-Sept-Oct 2018) heavier single cocoon weights were observed and within the standard range of acceptable single cocoon weight. This could be due to the effect of organic fertilizers that manifested on later years. The nutritional grade of mulberry leaves, on which the silkworm feeds, determines the health and growth of silkworm as well as the economic traits of produced silk. Thus, the amount and superiority of raw silk production and the resultant development of the sericulture sector depend on the mulberry leaves. Increasing use of organic products like vermicompost, vermiwash, farm yard manure, oil cakes, press mud plays an important role in the promotion of quality silk production (Singh, *et al.*, 2021).

Effect of rearing season

Single cocoon was significantly heavier in silkworms raised during the months of June-July 2017, followed by Nov-Dec 2017, Aug-Sept 2016, May–June and Sept-Oct 2018. The temperature during this season was 25.24-27.86°C and RH of 77.88% for young age and 25.65-28.06°C and RH of 79.93% for late age rearing. These were the colder months of the year that favored the growth of silkworms to produce heavier cocoons. During the kharif season, the cocoon weight was significantly higher under 75% organic + 25% inorganic fertilizer application (Tangamahlaer *et al.*, 2018). The lightest was observed during the months of May-June 2016 with a temp of 26.27-28.89°C and RH of 75.91% for young age and 26.19-27.96 °C for late age and RH 84.44 %. These could be due to the poor growth like larval weight and effective rearing rates that was observed during rearing period. The silkworms suffered from diseases that lead to poor yield and quality cocoons.

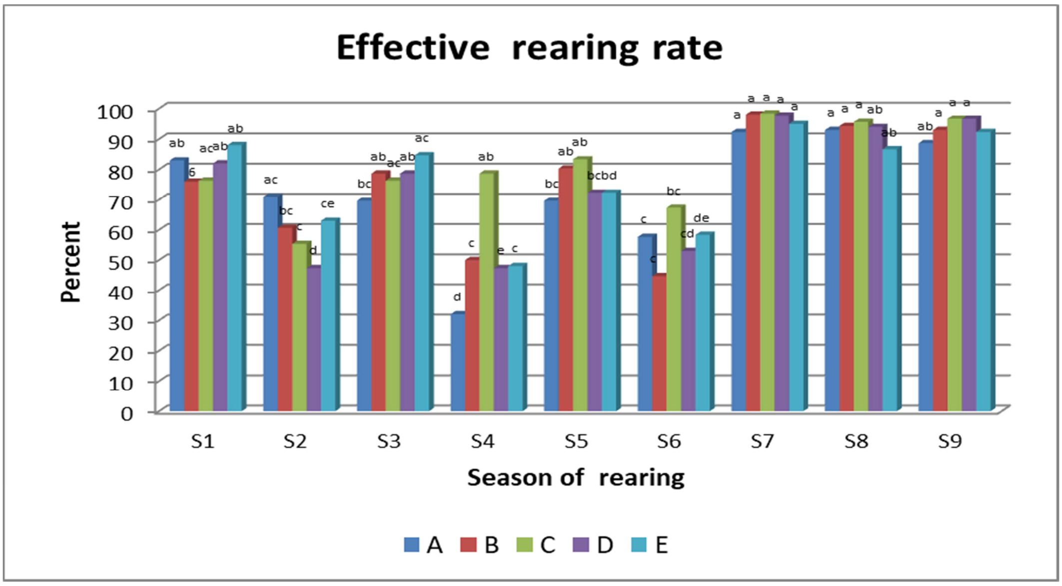

Fig. 2. Effective rearing rates (%) of silkworm fed with leaves in different cropping systems at each level of seasons of rearing

Cropping systems: A- Conventional, B- LEISA + Bio-fertilizer 1, C- LEISA + Bio-fertilizer 2, D- Organic farming + Biofertilizer 1, E- Organic farming + Biofertilizer 2. Seasons of rearing: S1 Nov.24-Dec.21, 2014; S2 March 4-31, 2015; S3 Sept. 29-Oct. 28, 2015; S4 May 10- June 6, 2016; S5 Aug 30-Sept 28 2016; S6 June 30-July 22, 2017; S7 Nov.15-Dec. 23, 2017; S8 May 22- June 12, 2018; S9 Sept. 27-Oct. 27, 2018

Comparison of treatment at each level of seasons

The single cocoon weight of silkworm was not significantly influenced by the cropping systems. The single cocoon weight ranged from 1.38 to 1.51 g during Nov-Dec 2014; from 1.28 to 1.36 g during March 2015 season; 1.30 to 1.48 g during Sept-Oct 2015; 1.06 to 1.11 g during May-June 2016; from 1.54 to 1.60 g during Aug-Sep 2016; from 1.68 to 1.76 g during June-July 2017; from 1.54 to 1.61 g during Nov-Dec 2017; from 1.51 to 1.57 g during Sept-Oct 2018 and from 1.42 to 1.46 g during the Sept-Oct 2018 rearing season. All of the farming systems had single cocoon weights that were within the standard cocoon weight (1.5 g) for high production in later years of rearing.

Single shell weight

Effect of farming systems

The single shell weight of silkworms fed with leaves grown in different farming systems was not significantly different with each other (Table 4). The result implies that any of the farming systems could be used as an alternative to growing mulberry for silkworm rearing to produce good quality or heavier single shell. It could be advocated however that the use of LEISA and Organic fertilizers + biofertilizers could be used instead of conventional farming to eliminate the adverse effect of continues use of fertilizers and other chemical inputs. The silkworm wastes that are available in most sericulture farms and other farm wastes are nutrient rich fertilizers. The silkworm excreta, containing 7.35% water, 13.88% crude protein, 1.44% raw fats, 15.41% raw cellulose, 47.15 % substances without nitrogen can be used as organic fertilizer or as chlorophyll source by alcoholic extraction (Buhroo *et al.*, 2018).

Effect of rearing season

Single shells was significantly heavier in silkworms raised during the months of June-July 2017 followed by the months of Nov-Dec 2017 and May-June 2018 and lightest was during the months of May-June 2016. These seasons were the colder months of the year that favored the production of filaments to constitute the single shells. The lightest was during the months of May-June, 2016 due to occurrence of pest and diseases as a consequence of high and fluctuating day to day temperature.

Comparison of treatment at each level of seasons

The single shell weight of silkworm was not significantly influenced by the cropping systems and rearing seasons. This implies that the newly developed cropping systems could be adopted as it has numerically heavier single shells through not significantly different with conventional farming. Further, these systems could be adopted in any of the growing seasons of the year through most preferred are during the colder months of the year.

Table 4. Single shell weight (g) of cocoons of silkworms fed with leaves in different farming systems and seasons of rearing

Rearing season	Conventional	LEISA+ Biof. 1	LEISA + Biof. 2	Organic+ Biof. 1	Organic+ Biof. 2	Season mean
Nov.24-Dec.21, 2014	0.263	0.280	0.277	0.273	0.280	0.274de
March 4-31, 2015	0.240	0.240	0.237	0.240	0.227	0.237f
Sept. 29-Oct. 28, 2015	0.257	0.263	0.277	0.273	0.280	0.270 e
May 10- June 6, 2016	0.183	0.203	0.203	0.167	0.200	0.191g
Aug 30-Sept 28 2016	0.293	0.283	0.300	0.280	0.293	0.290cd
June 30-July 22, 2017	0.343	0.353	0.347	0.347	0.330	0.344a
Nov.15-Dec. 23, 2017	0.320	0.330	0.317	0.293	0.310	0.314b
May 22- June 12, 2018	0.307	0.297	0.297	0.297	0.303	0.300bc
Sept. 27-Oct. 27, 2018	0.273	0.287	0.280	0.276	0.273	0.278de
Treatment mean	0.275	0.282	0.281	0.272	0.278	

In a column (season means), means followed by the same letter are not significantly different from each other at .05 level HSD

Table 5. Cocoon shell percentage (%) of cocoons of silkworms fed with leaves in different farming systems and seasons of rearing

Rearing season	Conventional	LEISA+ Biof. 1	LEISA + Biof. 2	Organic +Biof. 1	Organic +Biof. 2	Season mean
Nov.24-Dec.21, 2014	19.13	18.70	18.87	18.85	18.51	18.81bc
March 4-31, 2015	17.70	18.56	18.29	17.29	17.70	17.91c
Sept. 29-Oct. 28, 2015	19.61	20.30	20.27	20.55	18.97	19.94a
May 10- June 6, 2016	17.41	18.89	18.37	17.79	18.61	18.22ef
Aug 30-Sept 28 2016	19.08	18.46	18.71	17.81	18.91	18.60bc
June 30-July 22,2017	20.43	20.79	20.30	19.67	19.62	20.16a
Nov.15-Dec. 23, 2017	19.93	19.48	19.21	18.99	19.32	19.39ab
May 22- June 12, 2018	20.10	19.32	19.56	19.14	19.07	19.44ab
Sept. 27-Oct. 27, 2018	17.65	18.26	18.14	17.96	18.18	18.04c
Treatment mean	19.00	19.20	19.08	18.67	18.76	

In a column (season means), means followed by the same letter are not significantly different from each other at .05 level HSD

Cocoon shell percentage

Effect of farming systems

There was no significant effect of farming systems on cocoon shell percentage that ranged from 18.71 to 19.31% (Table 5). The result implies that any of the farming systems could be used as an alternative to conventional practices in sericulture. The use of sustainable practices however is highly advocated due to its potential benefits on the environment, people and silkworms. In this system, soft and mature leaves are suitable for feeding late age worms and this could be attained when mulberry is grown in good soil, optimum application of balanced fertilizer, suitable practices and assured rainfall/irrigation (Hikari, 1997).

Effect of rearing season

Cocoon shell percentage was comparable in silkworm raised during the months of Sept-Oct 2015 and June-July 2017, Nov-Dec 2017 and May-June 2018 and was higher than the rest of the treatments (Table 5). These seasons had a high and acceptable cocoon shell percentage that ranged from 19.69 to 20.1 percent. Madrid, 2010 also found out that silkworm hybrid DMMMSU 346 did not differ significantly in terms of CSP during wet, cool dry and dry season at SRDI and at the different seri-sites of Bacnotan, La Union.

Comparison of treatment at each level of seasons

The cocoon shell percentage of silkworm was not significantly influenced by the farming systems and rearing season. The conventional treatment had cocoon shell percentage of 17.21 to 20.43 % in different seasons. LEISA + biofertilizer 1 and biofertilizer 2 had CSP ranging from 18.46 to 20.79 % and 18.20 to 20.39% respectively. Organic farming + biofertilizer 1 and biofertilizer 2 had CSP ranging from 17.29 to 19.67 % and 17.70 to 19.62% respectively.

Table 6. Cocoon yield per box (kg) of silkworms fed with leaves in different farming systems and seasons of rearing

Rearing season	Conventional	LEISA+ Biof. 1	LEISA + Biof. 2	Organic +Biof. 1	Organic +Biof. 2	Season mean
Nov.24-Dec.21, 2014	22.77b-d	22.69b-d	22.36d	23.74a-c	26.63ab	23.64b
March 4-31, 2015	19.25d	16.01d-f	14.29e	13.07de	16.17de	15.76d
Sept. 29-Oct. 28, 2015	18.24d	20.35d-e	20.80de	20.94c	25.03a-c	21.07bc
May 10- June 6, 2016	6.89e	10.71f	17.38de	8.73e	10.24e	10.79e
Aug 30-Sept 28 2016	21.43cd	24.67bc	23.39bd	22.76bc	22.36bd	22.92b
June 30-July 22,2017	19.60d	15.29ef	22.99cd	18.63cd	19.59cd	19.22cd
Nov.15-Dec.23,2017	29.66a	33.14a	32.30a	30.19a	30.43a	31.15a
May 22- June 12, 2018	29.10ab	28.78ab	29.56a-c	28.94ab	27.61ab	28.80 a
Sept. 27-Oct. 27, 2018	27.43a-c	29.09ab	29.83ab	29.87a	27.55ab	28.75 a
Treatment mean	21.60b	22.30ab	23.65a	21.87b	22.84ab	

In a column (season means at each level of seasons), row means (treatment means) followed by the same letter are not significantly different from each other at .05 levels HSD

Cocoon yield per box

Effect of farming systems

Cocoon yield per box was significantly higher in LEISA+ bio-fertilizer 1 and biofertilizer 2 and Organic farming + biofertilizer 2 compared to other farming systems due to higher effective rearing rates and single cocoon weights recorded in these treatments (Table 6).

With more silkworms producing heavier cocoons, consequently more yields could be generated. The result implies that using the more sustainable farming systems could improve cocoon production in sericulture areas. The results could also be due to the better quality of mulberry leaves (proteins and moisture contents.) As observed in previous studies, pit planting method and fertilized with any of the following : 1)100-50-50 kg NPK/ha + 10 tons manure + green manure + mulch (LEISA I), 2) 50-50-50 kg NPK/ha + 10 tons manures + green + green leaf manure + mulch (LEISA II), and 3) 10 tons manure + green manure + green leaf manure + mulch (Organic Farming) had higher protein contents and acceptable range of moisture (high moisture contents for young-age worms and low moisture contents for late-age silkworms (Caccam and Mendoza, 2015). Furuque *et al.*, 2017 speculated that the improvement of mulberry leaf qualitative parameters and also added some of benefits like decomposer microbial association contribute for maximum level of nutrients to the compost which intern reflect on mulberry leaf and cocoon productivity**.** However, current observation was that the mulberry leaves of combined recommended basal dose of NPK+seriwaste compost treated plots have more nutritional value than that of other treatments which interns influences the successful and nutritious growth of silkworm, resulting rearing performance and cocoon production was comparatively increased. Likewise, the application of 1 t ha-1 gliricidia leaf manure provides21 kg N, 2.5 kg P, 18 kg K, 85 g Zn, 164 g Mn, 365 g Cu, 728 g Fe besides considerable quantities of 5, Ca, Mg, B, Mo etc. While, double amount of these nutrients was added / supplied when applied 2 t ha-l.. It improves mobilization of native soil nutrients in the soil due to production of carbon dioxide and organic acids during decomposition of the plant material, adds valuable nutrients such as N, P, K, Ca, and Mg to the soil (Rao *et al.*, 2011.)

Effect of rearing season

Cocoon yield per box was significantly heaviest in silkworm raised during the months of Nov-Dec 2017, May-June and Nov-Dec 2018 due to higher ERR and SCW. These seasons were the colder seasons of the year. The lightest was registered in silkworms raised during the months of May to June 2016 due low ERR and SCW. Cocoon yield was higher in middle pruning applied with 50 % organic + 50 % inorganic during kharif season (Tangamahlaer *et al.*, 2018). The success of sericulture industry is mainly based on leaf quality and appropriate environmental conditions for silkworm rearing. Mulberry leaves are exclusive source of nutrition for silkworm. Among the seasons, the spring season (February-March) showed better growth and cocoon characteristics followed by autumn (Oct-Nov), summer (March-April) and monsoon seasons (Aug-Sept). The better traits observed during favorable seasons than unfavorable seasons might be due to the influence of climatic conditions. The yield and economic traits were significantly influenced by various rearing season. The results of current study revealed that spring followed by autumn rearing seasons are suitable for bivoltine silkworm rearing in Uttar (Kumar *et al.*, 2013 as cited by Caccam *et al.*, 2024). An experiment on bioassay with multi × bi and multi × multi silkworm hybrids was conducted during two favorable and two un favorable seasons. The silkworms were fed mulberry leaves separately produced through six different treatment combinations under three packages. The result revealed that the application of reduced doses of Nitrogen and Phosphorus supplemented by various types of organic manures attributed cocoon yield and other economic characters of rearing and reeling at par with the control. Hence the package comprises of AM (Arbuscular Mycorrhizal) fungi-inoculated saplings variety S-1, green manuring with *Crotalaria junce* during rainy season and leguminous cover crop with *Ligna umbellata* during winter season along with the application of 50% reduced doses of N and P and full dose of K may be recommended for quality leaf yield, successful silkworm rearing and lower expenditure in mulberry cultivation under rainfed alluvial soil conditions (Saha and Setua 2006).

Comparison of treatment at each level of seasons

The cocoon yield per box was significantly influenced by the cropping systems and rearing seasons. Three growing seasons proved best in all treatments (Fig. 3). These were the seasons of Nov-Dec 2017 and May-June 2018 and Nov-Dec 2018. These seasons had colder temperature ranges that are favorable to the growth of silkworm. The lowest yield was recorded during the months of May-June 2016 and March 2015. At this season, the silkworms suffered from grasserie and flacherie diseases that triggered the low effective rearing rates and survived silkworms produced inferior cocoons (small and light).

Cost-return analysis of producing cocoons in different farming practices

For a hectare farm with a total population of 13,333 plants, a total production of 7,368.08, 8,585.65, 8,400.86, 7,322.22 and 7,149.42 kg of leaves could be produced in two growing cycle from conventional, LEISA + biofertilizer 1 and LEISA + biofertilizer 2 and Organic Farming I + biofertilizer1 and Organic Farming + biofertilizer 2 respectively (Table 7).

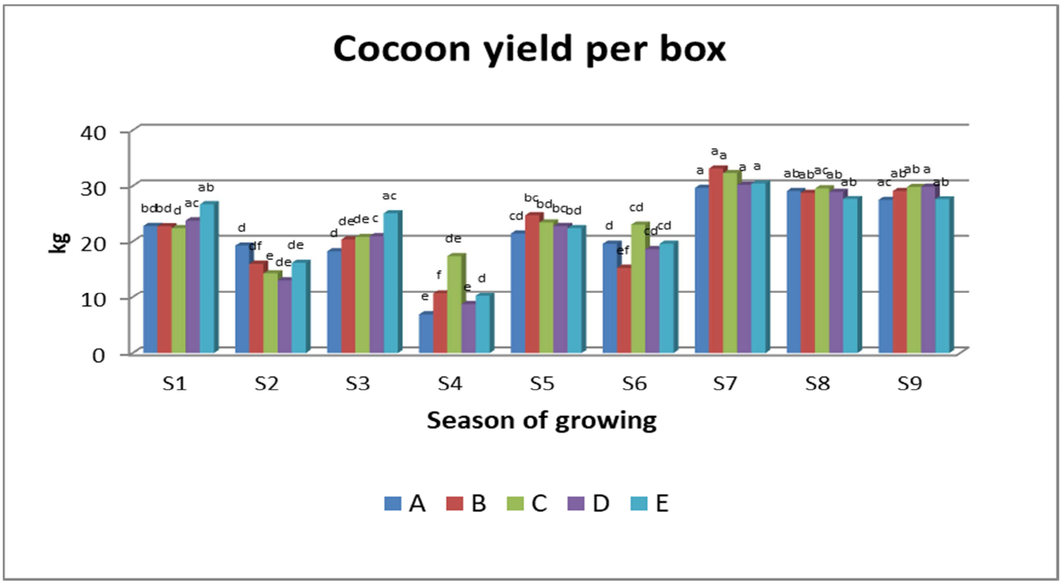

Fig. 3. Cocoon yield per box (Kg) produced by silkworm fed with leaves in different cropping systems at each level of seasons of rearing

Cropping systems: A- Conventional, B- LEISA + Bio-fertilizer 1, C- LEISA + Bio-fertilizer 2, D- Organic farming + Biofertilizer 1, E- Organic farming + Biofertilizer 2. Seasons of rearing: S1 Nov.24-Dec.21, 2014; S2 March 4-31, 2015; S3 Sept. 29-Oct. 28, 2015; S4 May 10- June 6, 2016; S5 Aug 30-Sept 28 2016; S6 June 30-July 22, 2017; S7 Nov.15-Dec. 23, 2017; S8 May 22- June 12, 2018; S9 Sept. 27-Oct. 27, 2018

Table 7. Computation of the potential yield of mulberry plants (two seasons) and the estimated gross income

Treatment description	Conventional	LEISA+Biof. 1	LEISA+Biof. 2	Organic+Biof. 1	Organic+Biof. 2
Variety	Alfonso	Alfonso	Alfonso	Alfonso	Alfonso
System of planting	pit	pit	pit	pit	pit
In-organic fertilization	150-50-50	75-50-50	75-50-50	10t kakawate	10t kakawate
Silk-waste compost		5t waste	5t waste	10t waste	10t waste
Biofertilizers		5kg vam	5kg vamri	5kg vam	5kg vamri
Plant population	13,333	13,333	13,333	13,333	13,333
Mulberry Prod'n/plant kg)	0.27631	0.32197	0.31504	0.27459	0.26811
Number of pruning	2	2	2	2	2
Total mulberry production/year (kg)	7,368.08	8,585.65	8,400.86	7,322.22	7,149.42
Food consumption (kg)	600	600	600	600	600
Capacity to rear(box)	12.28	14.31	14.00	12.20	11.92
Ave cocoon yield/box	19.69	20.41	21.93	19.71	21.49
Cocoon Production(kg)	241.80	292.06	307.05	240.53	256.07
Price per kg	200	200	200	200	200
Gross income Php	48,359.18	58,411.05	61,410.26	48,106.97	51,213.69

The higher production in LEISA I + biofertilizer 1 and LEISA 2 + biofertilizer 2 could be due to higher mulberry leaf production/plant in these treatments. Mulberry production per plant (g) was 276, 322, 315, 275 and 268g for conventional, LIESA biofertilizer 1, LEISA biofertilizer 2, Organic Farming 1 and Organic farming 2 respectively.

With a leaf consumption of 600 kg leaves per box, a total box capacity to rear of 12.28, 14.31, 14.00, 12.20 and 11.92 boxes for Conventional, LEISA biofertilizer 1 and LEISA + biofertilizer 2 and Organic farming + biofertilizer1 and Organic farming + biofertilizer 2 respectively. Considering the rearing performance of silkworms fed with leaves in different cropping systems, cocoon production per year was 241.80, 292.06, 307.05, 240.53 and 256.07 kg for Conventional, LEISA +biofertilizer 1 and 2 and Organic Farming + biofertilizer1 and 2 respectively. Higher cocoon production was recorded in LEISA + biofertilizer 1 and 2 due to higher capacity to rear and cocoon yield per box. The result implies that LEISA farming systems could improve the cocoon production of sericulture farms.

Gross and net income and ROI of producing cocoons in different farming practices

Gross income of cocoons was recorded highest in silkworms raised in LEISA + biofertilizer 2 farming system followed by silkworm raised in LEISA+ biofertilizer 1 due to higher mulberry leaf yields and cocoon yield per box in these treatments. Cocoons of silkworm raised in Organic + biofertilizer 2 ranked third followed by cocoons of silkworm raised in Organic farming+ biofertilizer 1 and the least was in Conventional treatment (see Table 8).

Table 8. Gross and net incomes and ROI of producing cocoons (main product) in different farming systems

Farming systems	Gross income Pesos	Expenses Pesos	Net income Pesos	ROI (%)
A= Conventional	48,359.18	39,999.25	8,359.93	20.90
B = LEISA+Bio-fertilizer1	58,411.05	34,308.46	24,102.59	70.25
C = LEISA –Biofertilizer2	61,410.26	35,081.00	26,328.28	75.30
D = Organic Farming + Biofertilizer1	48,106.97	30,867.07	17,239.91	55.85
E. = Organic Farming + Biofertilizer2	51,213.67	26,705.39	2,4508.31	91.77

With regards to net income and return on investment, the highest was recorded in cocoons raised in LEISA + biofertilizer 2, followed by LEISA + biofertilizer 1, Organic 2+biofertilizer 2, then Organic + biofertilizer 1 and the last was recorded in cocoons raised in Conventional practices. The higher net incomes and ROI on LEISA+ bio-fertilizer 1 and 2 and Organic + bio-fertilizer 1 and 2 treatments was due to higher gross incomes and lower expenses incurred in these treatments. The result implies that the uses of LEISA and Organic Farming + biofertilizers are more remunerative than the use of conventional practice.

Tangamalar *et al.*, 2018 also found out that middle pruning along with integrated nutrient management practice application of 50 % organic and 50 % recommended dose of inorganic fertilizer are found optimum for mulberry higher growth and yield attributes, yield economics of mulberry and silkworm with enhance net returns and B:C ratio in both kharif and rabi under irrigated conditions. The result implies that using LEISA and organic treatments are more remunerative in the long run. Very evident that mulberry leaf and cocoon yield increased in due time. Using the organic farming practices could reduce the potential risks of environmental pollutions besides adverse effects to the users and silkworm due to residues of the chemicals (fertilizers, weedicides, insecticides, and fungicides) used in the mulberry gardens.

These result coincides with the results of previous studies that average gross income was highest in LEISA 1, which also had the highest net income and return on investment, followed by Conventional II, Conventional I, LEISA II and Organic Farming 1. Considering combined oncomes from other products, highest combined incomes was recorded in LEISA I followed by Conventional II, LEISA II and Organic Farming 1. Increase of income from LEISA I and 2, Organic Farming 1 was very significant due to added food and fuel products.

Return on investment on the average, LEISA I and II, Conventional 1 and II and Organic Farming 1 had 30% higher ROI than the existing practice (Caccam and Mendoza, 2012).

Cost–return analysis on the production of cocoons and other products as affected by different farming systems

The use of sustainable cropping practices could lead to the production of other products that could be used in the farms. Silk wastes generated from silkworm rearing and converted into compost fertilizers are cheaper source of nutrients for the farms. Likewise, fuel woods could be produced from planting mulberry trees and kakawate trees aside from the green leaf manure from the leaves. These products were considered as they are made use by the farmers for energy and other purposes.

Net income was recorded highest in LEISA + biofertilizer 2 treatment followed by treatments in Organic farming + biofertilizer 2 and organic farming + bio fertilizer 1 then in LEISA + bio-fertilizer 1 treatment. The lowest was recorded in conventional treatment (Table 9).

Return on investment was highest in Organic farming + biofertilizer 2 treatment followed by Organic farming + biofertilizer 1, LEISA + biofertilizer 2, LEISA+ biofertilizer 1 treatment and the lowest was in Conventional treatment (Table 9). This could be due to higher combined gross income from cocoons and other products and the lower production cost incurred in the production system. The result implies that organic farming is a very remunerative endeavor. The use of organic farming practices in sericulture could be an alternative to mulberry production due to more diverse activities and products that resulted to higher combined income and return on investment (Caccam *et al.*, 2019). Sericulture is a short gestation period labor intensive enterprise which can go a long way in promoting inclusive growth and alleviating poverty in rural areas (Chauhan and Chauhan, 2013).

Table 9. Gross and net incomes and ROI of producing cocoons (combined product) in different farming systems

Cropping systems	Gross income Pesos	Expenses Pesos	Net income Pesos	ROI (%)
A= Conventional	55,009.18	40,399.25	14,609.93	36.16
B = LEISA+Biofertilizer1	65,061.05	34,708.46	30,352.59	87.45
C = LEISA –Biofertilizer2	68,060.26	35,831.99	32,228.28	92.94
D = Organic Farming + Biofertilizer1	61,406.97	31,667.07	29,739.91	93.91
E = Organic Farming + Biofertilizer2	63,913.69	27,305.39	36,608.31	134.07

These results suggest that there was an improvement in soil physical, chemical and biological properties in organic cultivation practices compared to conventional practice. The nutrient concentration (N, P, K, Fe, Mn, Cu and Zn) in mulberry leaf of organic practices was higher than conventional practice. Application of organic manures could improve the moisture retention capacity of soils and improve the water use efficiency and good crops can be harvested per drop of water (Yadav *et al.*, 2020) Benefit-cost ratio of both the cultivation systems showed that organic cultivation practice (BC: 1:1.74) is more viable than conventional practice (BC: 1:1.57). Benefit-cot ratio of both the cultivation systems showed that organic cultivation practice (BC: 1:1.74) is more viable than conventional practice (BC: 1:1.57).

Conclusion

Three systems were found productive as LEISA + biofertilizer 2, and biofertilizer 1 and Organic+ biofertilizer 2 due to heavier weight of ten mature larvae, and higher effective rearing rates and consequently heavier cocoon yield per box.

Rearing seasons significantly affected the silkworm growth and cocoon characters. The best seasons were from Nov-Dec 2017, May-June 2018 and Sept 27 –Oct 2018. These coincide with the colder months of the year that favored the growth of worms.

The weight of ten mature larvae, effective rearing rates, and cocoon yield per box were significantly influenced by the farming systems at each level of seasons.

Higher net income and return on investment (main and combined products) was recorded in LEISA + Biofertilizer1 and 2, Organic Farming + biofertilizer 1 and 2 compared with the cocoons raised in conventional practices.

Recommendation

Suistainable practices using the LEISA + biofertilizer 1 and 2 and Organic Farming + biofertilizer 2 could be an alternative to conventional farming due to heavier weight of ten mature larvae, and higher effective rearing rates and heavier cocoon yield per box. This also resulted to higher net income and return investment.

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