Fitness and Productivity of Silkworms Reared on different Mulberry Plant Varieties in Uganda

Sarah Babirye, Clet. Wandui. Masiga

Tropical Institute of Development Innovation
P.0 Box 379, Mukono-Uganda

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Abstract: The fitness and productivity of silkworms is largely influenced by the varieties of mulberry leaves they feed on. The overall aim of this research was to contribute to the development of the silk value chain through assessing the best variety for optimum growth and productivity of silkworms in Uganda. Hatching to the first spinning ranged from 21 to 24 days while feeding was done 2-3 times a day. Bombyx L. silkworms were fed with leaves of three mulberry varieties (Morus alba. L) i.e; Thailand, Local and Thika harvested from the research experimental gardens of Namasumbi village, Kyampisi Sub-county in Mukono district. Parameters like larval length, weight, survival rate, cocoon weight, pupae weight, shell weight and shell ratio were recorded on 10 randomly selected worms. Thailand variety was observed significantly superior in length (P=0.0001), weight (P=0.0001), survival worm (P=0.000), cocoon yield in grams (P=0.045), cocoon (n) yield (P=0.0038) shell weight (P=0.036), rate of cocooning ($p<0.05$). Percentage shell ratio also scored higher in Thailand (21.1%). No significant difference in pupa weight (P=0.06) , Total pupa yield (0.089) and filament length (P=0.5374).Thailand was significantly associated with early molting, spinning, and cocooning, converse to Thika and Local. The overall performance of B. mori in terms of fitness and productivity was significantly improved with Thailand variety. Therefore, it has the potential to enhance the commercial qualities of silk and hence recommended for higher yield of silk.

Keywords: Fitness, Productivity, Thailand variety, Bombyx mori.L

Introduction

Sericulture is one of the recent enterprises undertaken by farmers in Uganda that has improved the livelihoods of people. It is an Agro-based industry in developing countries like Uganda which has got a lot of land resources and human labour (D. Bharathi, 2019). Globally, the demand for silk exceeds the market supply. China which is the world leading producer of silk is currently with an annual turnover of 2-2.5 billion United States dollars from silk followed by India, Japan, South Korea (FAO, 1988). Across many Asian countries, mulberry (Morus spp) cultivation for silkworm rearing (Bombyx mori L) is considered to be one of the economic activities that secures income and foreign exchange (Datta, 2000 : Bothikar et al.,2014). In East Africa, sericulture is an income generating activity that improves the livelihoods of rural farmers (Aldolka , 2007). This is the art and science of rearing silkworms by feeding them on mulberry plants for the production of raw silk and its end products (Ogunleye & Johnson, 2012). Mulberry is a woody deciduous perennial plant that solely supports the growth of Bombyx mori and in turn cocoons and silk production (Nagaraju, 2002).

Sericulture in Uganda is an opportunity to create rural / urban employment and economic growth. This is due to its climatic conditions favoring the growth of mulberry for feeding the worms i.e temperatures between 24-28 °C and rainfall ranging between 800mm-2000mm (Couret et al., 2014: Wakitole Sori &

Wosene Gebreselassie, 2016). According to Adolkar (2007), good mulberry varieties are the key determinants of successful commercial sericulture. The growth and development of these larval worms for cocoon production majorly depends on the quality and nutritional elements of mulberry varieties (Seidavi et al., 2005; Mabel Caccam, 2012&Ruth Lalfelpuii1 et al, 2014). Mulberry leaf quality is determined by its chemical contents like protein, carbohydrates, minerals, and water and chlorophyll contents. This is ultimately reflected in the economic traits namely larval weight, cocoon and shell weight, etc that influence the yield and quality (Murugan and George, 1998). The quality of these leaves contribute to 38 percent for quality cocoon production (Rathanamma et al., 2005). Even other factors such as hybrid of silkworms also contribute to the growth of Bombyx mori larval growth (Ghimire, 2000). Leaf quality also differs among mulberry varieties hence a difference in silkworm rearing performances and cocoon production. The quality and quantity of mulberry leaves on a plant depends on the mulberry variety and this directly influences the size of the silkworm, cocoon weight and cocoon filament harvested respectively (Adolkar, 2007). Mulberry varieties that have higher yields that contain better nutritional elements are always desirable to feed the silkworms. Silk worms prefer leaves containing higher amounts of moisture, protein content, sugars, carbohydrates and fibre content (ESCAP 1993). If the farmer feeds the worms on the best quality and variety of mulberry in all the stages of development, FAO, 1990 reports that he doesn't only reduce the rate of mortality but also increases on the survival percentage of larval worms and cocoon harvest. Young, tender and succulent chopped leaves are the best to feed on the worms in the 1st and 2nd instar because they contain 78-80% water, 30% protein and at least 12% carbohydrates. 2nd instar only requires 76-77% water, 27% protein and 18% carbohydrates (ESCAP 1993). Lower moisture content leaves but with higher protein are suitable for mature worms ((Veerapura et al., 2013).

Researchers have done several reports on the evaluation of mulberry varieties on silk worm growth and development. However, in Uganda, the fitness and productivity of silkworms reared on different mulberry plant varieties has received limited attention. As such, development of sustainable silk value chain/ industry is curtailed due to limited information and knowledge . Hence, this study evaluated the Fitness and Productivity of Silkworms Reared on different Mulberry Plant Varieties in Uganda.

Results will support development of a knowledge-based and economically viable silkworm value chain in Uganda.

Materials and Methods

Disease free laying of Bivoltine hybrid Huakang No.3 silkworms, a breed developed by Academy of Agricultural sciences in China were collected and hatched under suitable conditions of temperature $25 \pm 5°C$ with relative humidity 80±5% and humidity (70%) at the Tropical institute of research and development sericulture centre (TRIDI) in Namasumbi village, Kyampisi Sub county in Mukono district as recommended by M.H **Hussein (2005)**. This investigation was done between January-February 2021 to evaluate the Fitness and Productivity of Silkworms reared on different mulberry plant varieties in Uganda. Materials required for an experiment included wooden trays (1m *1m), basins, knives, litter baskets, broom, news paper ,covering trays, feathers, weighing scale ,cleaning nets, charcoal stove and disinfectants .The incubated eggs hatched to tinny worms. Uniform hatching was attained by keeping the eggs in the black box a day to hatching. This prevented the early maturing embryos from hatching and the late maturing embryos were given enough time to catch up with the matured embryos. These newly hatched worms were transferred to the rearing trays through a process called brushing. News papers were placed at the bottom of rearing trays which was moist and covered with plastic sheet to conserve humidity. Silkworms were reared on carefully identified disease free mulberry leaves that included Thailand, Local variety and Thika varieties. Each treatment consisted of 4 replicates with 100 larval worms per replicate. In the 1st and 2nd instars, mulberry leaves for the three (3) varieties were chopped in small sized pieces ranging from 0.5-1cm by knives and sprinkled on top of the selected silkworms that were laid on the cleaned wooden trays.

In order to remain consistent , uniform quantity of mulberry leaves were measured with a weighing scale and given on each stage i.e 4:6:8:20 and 30 grams respectively. On the 1st day of the 1st instar, larval worms were fed once, at 8:00am and twice from 8:00am-8:00pm on the 2nd and 3rd day respectively. For the rest of the instars, worms were fed thrice or four times a day on whole leaves. The 3rd to 4th young , tender and succulent leaves from the tip of a shoot were fed to the worms in the 1st instar , followed by the 5th-6th leaves (4 leaves) in the 2nd instar . The rest of the remaining mature and coarse leaves were fed to the 4th and 5th instars at uniform time intervals depending on the need of the feeds on the rearing trays. Leaves were harvested early in the morning and later in the evening. In most times they were harvested in gunny bags (Veerapura et al., 2013).

Parameters like length, weight of the worms, cocoons and filament length were attained by randomly selecting 10 worms from each treatment and results recorded on every second day of each instar.

Timely harvesting of cocoons was done on the sixth (6th) day after spinning and before the emergency of the month to prevent destroying the cocoons/filament. Insects were killed by heat under the sun and fumigated with ammonium phosphate tablet. Weight of the pupa, shell weight, cocoon filament length were recorded on the randomly 10 selected cocoons from each fed variety and means recorded.

To get the cocoon filament length (m), the silk thread was carefully removed from the cocoon by the delicate process known as reeling and the length of that thread was measured in meters using the epprouvette as calculated below:

Filament length = Revolutions of epprouvette*wheel Circumference (m)

To calculate the percentage shell ratio, 10 fresh cocoons were randomly selected and weight of a single shell cocoon was recorded. Cocoons were cut to separate the pupa and the cocoons. The shell weight was noted to calculate the shell ratio as followed by this formula (Lee, 1999).

$$\text{Shell ratio} = \frac{\text{Shell weight}}{\text{Weight of cocoons}} * 100$$

Data collected on various parameters was subjected to statistical analysis of variance for significant differences and analyzed using PAST 4.04 soft ware.

Experimental design

Parameters	Methodology
Weight of 10 mature larvae	10 mature larva were randomly selected and measured from 3rd instar to the 5th instar
Survival worms	These were closely monitored at each stage of development. All worms found alive were recorded and dead discarded Survival worms = Count of survival worms
Single cocoon weight	10 cocoons were randomly selected and measured. Average recorded
Good cocoons harvested	Good cocoons and rejects were counted while harvesting = Total number of cocoons harvested- Rejects
Filament length	Filament length = Revolutions of epprouvette*wheel Circumference (m)

Results

There is a significant difference in the mean length (df=2, f=46.85, p=0.0001) and weight (df=2, f=27.52, p =0.0001) of silkworms fed on the different mulberry varieties. The post hoc mean separation showed that silk worms that fed on Thailand

had the highest mean larval worm length and weight (3.94± 0.2 , 18.09± 2.69)) while lowest in local variety (2.81 ± 0.2, 9.58 ± 1.93) respectively. Table 1

The survival analysis was significantly different (df=2, f= 8.119 p=0.00092) up to larval cocoon stage in the three experiments. Mean separation showed that silkworms that fed on Thailand had the highest worm survival variety (34.6 ±3.2) and lowest in local variety (22.8±3.0) Table 1.The results from the single cocoon weight revealed that weight of silkworm Bombyx mori L. varied from 1.77g to 1.92g.The highest single cocoon weight was observed in the larvae fed on leaves of Local variety (1.92±2.19) followed by Thika (1.76±2.38) and the lowest single cocoon weight was recorded in larvae fed on Thailand variety (1.76±2.38). Thailand was significantly associated with early molting, spinning, and cocooning, converse to Thika and Local as seen in Figure 1. Furthermore, the longest filament length (m) was recorded in larvae fed on Thailand (1177 m) and least in Thika (1158 m). There was no significant mean difference (df=2, f= 0.6311,p=0.5374). The post hoc mean separation showed that silk worms that fed on Thailand had the highest filament length (994.6 ± 33.5) while lowest in Thika variety (940.8±26.4). Table 1. Cocoon yield per 10 larvae brushed worms was significantly increasing with those that were fed on Thailand variety (P=0.054). Maximum total yield of cocoons (g) was obtained in Thailand fed variety (68.6±16) , followed by Thika (27.6±12.6) and lastly Local variety (27.3±10.4). There was a significant difference in the shell yield P =0.0383) among varieties. Maximum shell yield (g) was obtained in larvae worms that fed on Thailand variety (14.4±3.4), followed by Thika variety (5.7±2.6) and lastly Local variety (5.1±1.9). Percentage shell ratio scored high in Thailand (21.1%) , Thika (20.6%) and lastly Local (19.0%) .Table 3 . There was no significant difference in the total pupa yield P =0.089). Pupa yield (g) for Thailand variety was greatest (50.5±11.8), Thika (21.38±9.75) and Local variety (22.56±8.579). Number of cocoons, shell weight, were also significant with Thailand variety (P =0.03844, P=0.03838) respectively. Pupa weight however did not show a significant difference (0.06). Variety local recorded significantly lowest number of cocoons (34) while Thailand the highest with (76) in the duration of 10 days of production. Table 2.

Data on the rate of cocooning was observed significantly different. Results revealed that the cocoon production against number of days was significantly increasing with Thailand variety (P<0.05). Larval worms that fed on Thailand mulberry variety cocooned earlier from the 21st day while Thika and Local started cocooning on the 24th day. Figure 2

Table : 1 Effect of Mulberry varieties on Silkworm Cocoon productivity

Variety	Larval weight	Larval Length	Cocoon (g)	No. Cocoons	Single-Cocoon Weight	Single Shell Weight	Shell Weight (Yield)	Single Pupa Weight	Pupa (Yield)g	Survival worm	Filament Length (M)
Thailand	18.1±2.7	3.94±0.2	68.6±16.1	39.7±9.3	1.76±2.38	0.3632±1.29	14.4±3.4	1.271±2.58	50.5±11.8	34.6±3.2	994.6 ±33.5
Thika	10.5±1.85	3.27±0.2	27.6±12.6	15.7±7.2	1.76±2.38	0.3632±1.33	5.7±2.6	1.362±1.06	21.38±9.75	29.2±2.97	940.8±26.4
Local	9.58 ± 1.9	2.81 ±0.2	27.3±10.4	14.2±5.2	1.92±2.19	0.363±4.56	5.1±1.9	1.589±1.09	22.56±8.579	22.8±3.0	954.4± 43.5
P value	0.0001	0.0001	0.054	0.03844			0.03838		0.089	0.00092	0.5375
F value	27.52	46.85	3.242	3.686			3.688		2.639	8.119	0.6311

ANOVA Kruskal- wallis ; Tukey Test: Mean within a column is significant at P< 0.05

Table 2: Three Mulberry varieties on Total cocoon, shell and pupa yield

Days	Variety	Cocoons	Yield(Coc-g)	Yield (Shells-g)	Yield(Pupa-g)

15	Thailand	1	1.73	0.3632	1.2712
16	Thailand	4	6.92	1.4528	5.0848
17	Thailand	9	15.57	3.2688	11.4408
18	Thailand	15	25.95	5.448	19.068
19	Thailand	47	81.31	17.0704	59.7464
20	Thailand	50	86.5	18.16	63.56
21	Thailand	60	103.8	21.792	76.272
22	Thailand	65	112.45	23.608	82.628
23	Thailand	71	122.83	25.7872	90.2552
24	**Thailand**	**75**	**129.75**	**27.24**	**95.34**
15	Thika	0	0	0	0
16	Thika	0	0	0	0
17	Thika	0	0	0	0
18	Thika	0	0	0	0
19	Thika	4	7.04	1.4528	5.448
20	Thika	6	10.56	2.1792	8.172
21	Thika	20	35.2	7.264	27.24
22	Thika	25	44	9.08	34.05
23	Thika	31	54.56	11.2592	42.222
24	**Thika**	**71**	**124.96**	**25.7872**	**96.702**
15	Local	0	0	0	0
16	Local	0	0	0	0
17	Local	0	0	0	0
18	Local	0	0	0	0
19	Local	1	1.92	0.363	1.589
20	Local	7	13.44	2.541	11.123
21	Local	25	48	9.075	39.725
22	Local	35	67.2	12.705	55.615
23	Local	36	69.12	13.068	57.204
24	**Local**	**38**	**72.96**	**13.794**	**60.382**

Table 3: Effect of different varieties of mulberry leaves on percentage shell ratio

Variety	Total-no-cocoon harvested(g)	Total weight	Weight(g/10)	Shell weight(g/10)	Pupa weight(g/10)		%shell Ratio
Thailand	75	130	1.733	0.3632	1.2712		21.1
Thika	71	125	1.76	0.3632	1.362		20.6
Local	38	73	1.92	0.363	1.589		19.0

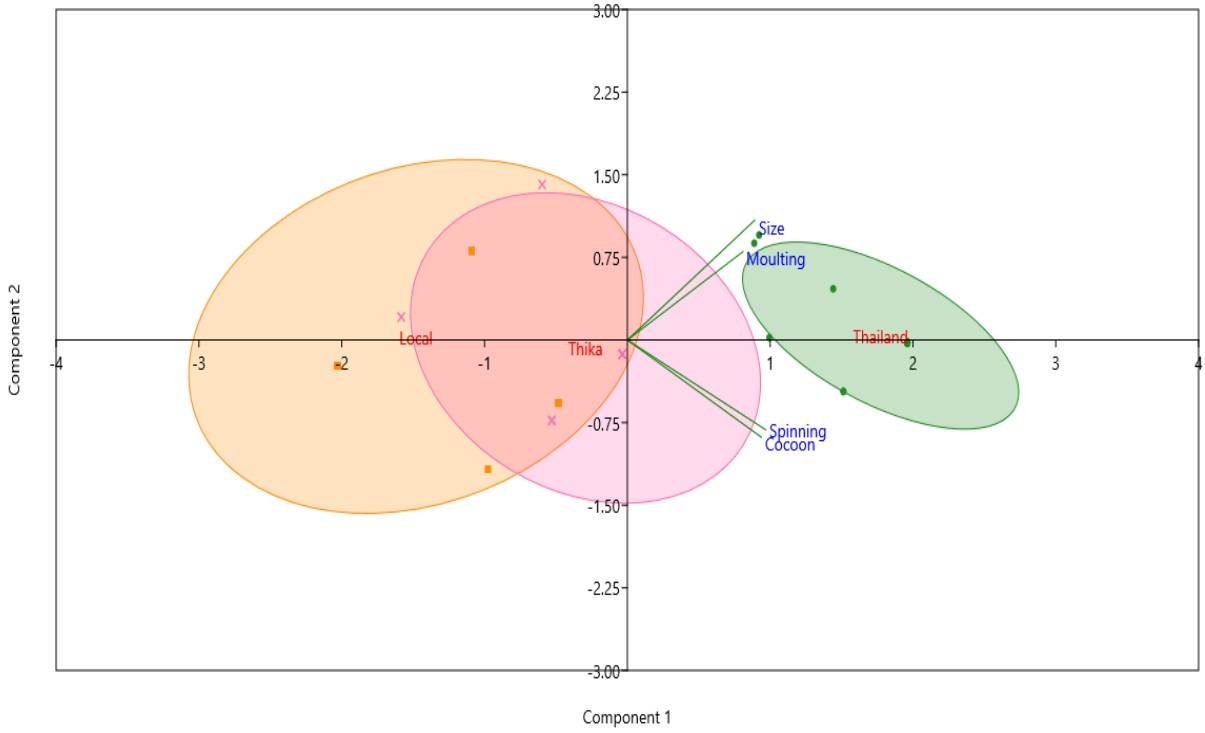

Figure 1: Effect of three Mulberry varieties on growth performance of Silkworms (vigour)

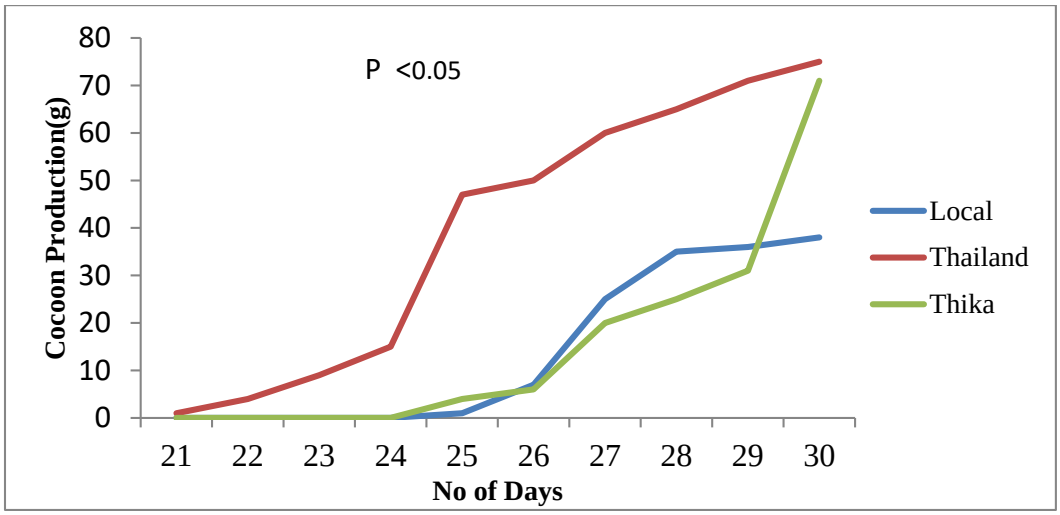

Figure 2: Effect of three Mulberry varieties on rate of cocooning of larval worms

Discussion

Sericulture is one of the recent enterprises undertaken by farmers in Uganda that has greatly improved the livelihoods of people. The fitness and productivity of silkworms reared on different mulberry plant varieties vary depending on the quality and quantity of mulberry leaf which in turn is indicated by the commercial characteristics of the cocoons (Veerapura et al., 2013). Mulberry plants are enriched with varied amounts of protein content that determine the size of the larval worms. This study found a significant difference between the worms that fed on Thailand, Thika and Local variety leaves in length and

weight. The length and weight of larval worms were significantly greater in worms that fed on Thailand leaves. This variation may be due to nutritional composition of the leaf. Results of different researchers also revealed that the quality and content of mulberry leaves consumed caused differences in the performances of silkworm larvae (A.R.Bizhannia, 2008: Masoud Alpanah et al, 2020). Therefore, feeding is a key determinant in sericulture industry. Gangawar (2010) in his findings found out that among eight mulberry varieties i.e. S1, S146, S1635, AR12, AR14, TR10, BR2 and K2 evaluated for nutritional potential by silkworm rearing experiments, the larvae that fed on BR2 variety leaves showed higher larval weight and improved economic traits like cocoon weight, shell weight and silk percentage in comparison to other varieties. According to Motahari et.al (2009) , all varieties have substantial amounts of nutrients but with varying proportional amounts for example, Thailand variety has high protein content, Kava and Embu rich in macronutrients while Thika and Limiru is rich in micronutrients. Young silk worms prefer feeding on young leaves because there are more tender, succulent and nutritious while late age worms feed on mature leaves with less moisture (Veerapura et al., 2013). All varieties show a drastic increase in the 5th instar due to maximum food consumption and growth rate. Motahari et al (2009) in his findings showed that the weight gained in silkworms fed with local variety also recorded the lowest among other varieties.

The rate of survival was significantly observed in worms that fed on Thailand mulberry leaves.

Larval worms that feed on protein rich plants were disease resistant, had better survival up to cocoon stage and more successful than those that feed on less rich protein (Murugan,1998). Factors contributing to increased rate of dead larva during the rearing stages are either internal or external (Couret et al., 2014). In agreement with Adeduntan (2015), this study revealed that the varieties of mulberry leaves had significant effect on the survival rate of the larval worms. Those fed on Thailand leaves registered a higher survival rate compared to Thika and local varieties. Results were also similar to Adolker (2007) who recorded highest survival in Thailand (96.9%) followed by Thika and Kanva-2/M5 in both rainy season (S1 and S2). Similar findings observed high larval protein in s1635, followed by V1 and least in local variety (Lalfelpuii et al, 2014).

Cocoon production is another important parameter used to evaluate the effects of varied nutrients in mulberry varieties. Sericulture industry hence requires maximum attention right from growing mulberry plants to cocoon production. Present study showed that the total cocoon production was lowest in worms that fed on local variety leaves. This significant low production ($p \leq 0.05$) among other factors is attributed to un availability of some nutrients and minerals in the leaves. This is also supported by Adolker, (2007) that the variety of mulberry leaves have significant effect on the amount of cocoon produced. For example, in Central Kenya, Thailand, Thika, Kanva-2/M5 and S-36 performed better for silk production on the cocoon yield. Motahari et.al (2009) compared performances of larval worms fed on varieties of mulberry leaves. In their research findings, the highest numbers of cocoons were obtained when the leaves of Wasemidori and Kenmochi cultivars were used. According to Masoud et al., (2020), one of the key determinants of Sericulture industry is the good mulberry variety. Their research showed a significant difference in the yields of the treatments fed with Kenmochi, native mulberry and black mulberry varieties.

Cocoon weight and shell weight are the important traits to evaluate productivity (Gaviria et al, 2006). Varieties of mulberry leaves have significantly higher effect on percentage of shell weight and pupa weight (Adeduntan, 2015) . Shell weight indicates the amount of raw silk that can be reeled from the given quantity of fresh cocoons (Veerapura et al., 2013). According to Nguku E.K (2007), the findings show no significant difference on pupa and shell weight among larval worms that fed on various mulberry plants. Various researchers

indicated that the cocoon filament varies with leaf varieties fed on silkworms (S. G. Pakhale , 2014 ; Lalfelpuii et al, 2014). Although there was no significant difference in the filament length among varieties, this research recorded that silkworms that were fed on Thailand leaf variety produced the longest filament compared to other varieties. This can be suggested that Thailand has got few reeling breaks compared to other varieties (Lalfelpuii et al, 2014) . Similarly, Thailand variety showed the highest trends in improving the filament length (Adolker, 2007). Lalfelpuii et al (2014) found out that local variety recorded the shortest filament length among S1635 and V1. FAO (1999), reports that cocoon filament length ranges from 600-1500m and 80% only can be reelable. In a study by S. G. Pakhale (2014) , longest filament length was recorded in larvae fed on variety V-1 (836.66 m) followed by Kanva-2 (798.33 m), S-54 (780.00 m) and S36 (775.00 m) and shortest in BER -779 (680.00 m) variety of mulberry. The economics of reeling also depends on the quality of cocoons produced (Kumar et al, 2014). Long and un-breakable filaments are good attributes in commercialized sericulture (Nguku E.K et al ,2007).

Uniformity in molting, spinning and cocooning were highly observed in worms that fed on Thailand leaves converse to Thika and Local. In a study done by (Veerapura et al., 2013) Tr8 mulberry germplasm variety was more superior in moulting than other varieties

CONCLUSION AND RECOMMENDATION

Thailand plant variety recorded the best suitable leaves for feeding the Bombyx L. silk worms. It is therefore recommended to breeders as well as silkworm rearers to use this variety for better yields, healthy silkworms and commercial production of silk worm cocoon. However, further research is needed to evaluate other varieties of mulberry plants on silkworm performance for sustainable growth and development of sericulture industry in Uganda.

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