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The Effective Influence of Temperature on the Varied Characteristic of Silkworm: A Review

Sangeeta Sarkhel, Shashibala Shrivastava*, Manjusha Pouranik
P.G. Dept. of Zoology, Mata Gujri Mahila Mahavidyalaya (Auto.)
Jabalpur- pin code. 482001. MP
*Dept. of Zoology, Govt. College, Kundam, Jabalpur- pin code.482001, MP
Email : sangeeta.sarkhel@gmail.com
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Abstract : The mulberry silkworm (*Bombyx mori L.)* is very delicate, highly sensitive to environmental fluctuations and unable to survive in extreme nature. The seasonal fluctuations affects the morphological as well as biochemical aspects of silkworm such as length & weight of larvae and diameter & weight of cocoon along with protein content of silk-gland and cocoon. The environmental conditions vary day to day and season to season highlight the requirement of physical parameters like temperature, light and humidity for sustainable cocoon production. The present review deals with the role of temperature on the growth and development of silkworm and its silk-gland. In this study CSR (multivoltine) and CV (bivoltine) hybrid is taken as raw materials. *Bombyx mori* L. CSR is a multivoltine crossbreed that produces high quantity of silk. The length and weight of worms and glands are directly related to the yield of silk, higher larval weights leads to higher production of silk. CV is also a thermo-tolerant bivoltine crossbreed
that produces high quality of silk.

Keywords: *Bombyx mori,* CSR hybrid, CV hybrid, bivoltine, multivoltine.

Introduction

Sericulture or silk farming is rearing of silkworms for the production of raw silk. Sericulture has become one of the most important cottage industries in number of countries like China, Japan, India, Korea, Brazil, Russia, Italy and France. Today, China and India are the two main silk producers, together manufacturing more than 60% of the world production each year. Silk is discovered in China about 2700 BC. Silk production today is a blend of ancient techniques and modern innovations. India is the second largest producer of raw silk after China and the biggest consumer of raw silk and silk fabrics. In India, sericulture is not only a tradition but also a living culture, It is a farm-based, labour intensive and commercially attractive economic activity falling under the cottage and small-scale sector. India is a home to vast variety of silk secreting fauna which also includes an amazing diversity of silk moths to achieve the unique distinction of being a producer of all the five commercially traded varieties of natural silks namely, Mulberry, Tropical Tasar, Oak Tasar, Eri and Muga (Giridhar *et al*., 2010).

Silk from the Silkworm is proteinaceous in nature and considered as the queen of fibers. The bulk of commercial silk produced in the world is mulberry silk that comes from the domesticated silkworm, *Bombyx mori* which is a monophagous and voracious eater of the leaves of mulberry plant. Silkworm are lepidopteran insects and their caterpillars spin a cocoon of silk at the end of the larval stage by silk glands.

The silk is a continuous filament fiber consisting of fibroin protein secreted from two salivary glands in the head of each larva and a gum called sericin, which cements the two filaments together. World silk production has approximately doubled during the last thirty years in spite of man-made fibers replacing silk for some uses. Silk is a great invention of the Chinese people and one of its significant contributions to world civilization. The constant innovation of mulberry plantation techniques, weaving techniques and silk weaving arts as well as the inventions by numerous craftsmen consistently pushed the advance of silk-related techniques and artistic level.

The production of silk depends upon several factors of which the effect of the environmental factors such as biotic and abiotic factors is of vital importance. Silkworm as it is a poikilothermic (cold blooded) insect so the temperature is one of the important abiotic factors, which plays a major role on growth and productivity of silkworm (Benchamin and Jolly, 1986). It has been proved that the relatively lower temperature is preferred by the late age silkworms than younger age. However fluctuation of temperature during different stages of larval development was found to be more favourable for the growth and development of larvae than constant temperature. Many researches are documented demonstrating that good quality cocoons are produced within a temperature range of 22-27°C and above these levels causes the cocoon low grade (Suresh Kumar and Harjeet Singh, 2011). Therefore, it is highly significant to identify optimum temperature range in addition to other parameter so that developemental stages of the silkworm can withstand adverse climatic conditions. Accordingly, the present review was focused on impact of temperature on growth parameters like length and weight of different instars of the silkworm.

Factors affecting the physiology of insects

Factors mainly influence the physiology of insects are temperature and humidity. Temperature is considered to be the most important factor for silkworm egg hatching. It affects the duration of incubation, uniformity and percentage of hatching, quality of the cocoons and the voltinism of silkworm. Despite wide fluctuations in their surroundings, insects show a remarkable range of adaptations to fluctuating environmental conditions and maintain their internal temperature and water content within tolerable limits. Adaptation is a complicate and vibrant state that widely differs from species to species. The effect of temperature on egg hatching depends also on whether the hatching is achieved naturally or artificially. Rearing temperature directly affects the physiology of the silkworms, in nutrient absorption, digestion, blood circulation and respiration. The mulberry silkworm is very fragile, highly sensitive to environmental fluctuations, and unable to survive extreme natural fluctuation in temperature and humidity.

The silkworm is the larva or caterpillar of the domesticated silkmoth, *Bombyx mori*. It is an economically important insect, being a primary producer of silk. Larvae are monophagous and feed only on mulberry plants. The larva will molt four times before spinning a silk cocoon of one continuous fiber for pupation. The growth and development of silkworm is greatly influenced by environmental conditions therefore, *Bombyx.mori* is fully domesticated and cannot survive without the assistance of man. The biological as well as cocoon related characters are influenced by temperature, rearing seasons, quality mulberry leaf, and genetic constituition of silkworm. The cocoon crop success is determined by several factors including weather conditions during rearing, nutrition and ability of the silkworm races to deliver under stress environment. Silkworm is highly sensitive to changes in the environment such as temperature, humidity and photoperiod which govern the lifecycle of the silkworm and ultimately the cocoon crop. Voltinism of the successive generations of the silkworm strains depends upon the environmental conditions during various stages. Several researchers have tried to establish the rearing requirements of the silkworm for successful cocoon crop on commercial basis as well as for egg production to ensure continuity of the process. The seasonal fluctuations in the environmental components considerably affect the genotypic expression in the form of phenotypic output such as larval weight, cocoon weight, shell weight and so on. The deviations in the environmental conditions during the last decade highlight the need of managing temperature and relative humidity for sustainable cocoon production. India enjoys the comfortable second position for the production of silk in the world next only to China.

Role of Temperature on Growth of Silkworm

Temperature plays a crucial role on the growth of the silkworms. Temperature will have a direct effect on various physiological activities of silkworms as they are cold-blooded animals. Rearing temperature directly affects the physiology of the silkworms, in nutrient absorption, digestion, blood circulation and respiration. The first three instars of silkworms require high temperature i.e. 25^0C. However in the next two instars, the need in temperature decreases i.e. 23^0C-24^0C. The ideal temperature for healthy growth of silkworm varies according to its devlopmental stage and variety. Increase of temperature increases the growth of silkworm. However, very high temperature imbalances the metabolic activity and the silkworm, thus becomes unhealthy. High temperature also affects the quality of leaf in the rearing bed. In case of lower temperature, the larval duration is extended due to low metabolic activities. Ideal temperature can be maintained by adopting the following methods. Low temperature can be increased by using electric heater preferably connected with thermostat or by burning charcoal without emitting smoke. High temperature can be brought down by keeping the premise cool through shade, sprinkling water, providing false ceiling or covering roof with dried plant material. Temperature influences to alter various physiological aspects which in turn reflect on silk characters and production. Therefore wide fluctuations of temperature should be avoided. The varietal differences affect the silkworm egg yield (Ahsan and Rahman, 2008).

Verma *et al.* (2011) investigated that larvae were reared at different temperature and RH and pupa were formed. Mortality rate and weight of pupa were recorded at different temperature. Weight of pupa was 2.99gms reared at 24ºC & 80% the weight of shell was 0.370gms. (Benchamin and Jolly, 1986) has stated that the success of sericulture industry depends upon several factors of which the impact of the environmental factors such as biotic and abiotic factors is of vital importance. Among the abiotic factors, temperature plays a major role on growth and productivity of silkworm, as it is a poikilothermic insect.

The present study concludes that development of larvae were better obtained at temperature 22-24°C and 75-85% relative humidity. It is also observed that average weight of pupa and weight of shell was more at temperature 22-24°C and 80-85% relative humidity. Study reported that the occurrence of unfertilized eggs was more common in summer as compared to other seasons (Biram *et al.,* 2009). Larvae and cocoon exposures to 35°C or above results in poor performance of silkworm moths in relation to egg number and egg fertility and high temperature during rearing,cocooning, mating and oviposition induced unfertilized egg layings. Datta *et al.,* (2001), found that low temperature is always better than highertemperature with reference to productivity of silkworm and larval duration for different instars. It has been demonstrated that good quality cocoons are produced within a temperature range of 22-27° C and that cocoon quality is poorer above these levels (Datta *et al.*, 1996, 1997) . Devi, R. and Karuna, T., (2012) has observed that the temperature above 30°C directly affects the health of the worm. If the temperature is below 20°C all the physiological activities are retarded. The temperature stress causes a number of abnormalities at the cellular level as the normal pattern of protein synthesis halts (Feder, 1996 and Feder *et al.*, 1996). Another important effect of temperature (or stress of any kind) is the unfolding of cellular proteins. Cellular proteins are typically folded in their native conformations while functioning in cells. This process can result in aggregates of unfolded protein that at best diminish the pool of functional proteins and at worst are cytotoxic. Giridhar *et al.* (2010) stated that Production of Vanya silks (Tasar, Eri and Muga) during 2010 -11 were 1166 MT, 2,760 MT & 124 MT respectively, corresponding to 803 MT, 2460 MT & 105 MT produced during the year 2009-10.Vanya silks viz., Tasar and Eri have shown significant increase in production of raw silk during the year 2010-11.

Renuka & Shamitha (2014) have observed that the post cocoon parameters were highest during winter with occasional variations providing an insight into the physiological strategy of survival adopted by this silkworm species during winter (18 ° – 28° C). Among the abiotic factors, temperature plays a major role on growth and productivity of silkworms. He has also concluded that the polyvoltine breeds reared in tropical countries are known to tolerate slightly higher temperature and adjust with tropical climatic conditions.

Hugar and Kaliwal (1998) observed that the 5th instar larvae were most active instar and

hub of larval activity during which larvae build up large quantities of food reserves which are harvested for cocoon spinning, metamorphosis and reproduction. Hussain *et al.* (2011a) studied that higher temperature, especially more than 30°C in the breeding conditions did not favor the larval growth and finally lead to larval death. He (Hussain *et al*., 2011b) also indicated in his another study that the variations in rearing conditions of temperature and RH resulted in poor performance of non-feeding stages (pupa & adult) of moth. Jordan (2002) studied that the effect of varied temperature on various stages of silkworm and also observed silk gland. Silk gland of Bombyxmori is a typical exocrine gland secreting large amount of silk proteins. It is consisting of modified labial/salivary glands located at the two lateral sides under the alimentary canal. Each gland is basically a tube made of glandular epithelium with two rows of cells surrounding the lumen. Kaleem *et al.* (2011) has observed that varying sets of temperature and humidity affect both quantity and quality of silkworm as 40% mortality of larvae was recorded at 25° C.

Khan (2014) stated that the optimun temperature for larvae cultivation range between 25 and 26°C was for better yield of cocoon. Kremky and Michalska (2004) reported that silk worm larvae spun best cocoon at 25°C and 75 % RH. Many other researchers highlights that good quality cocoons are produced within 25 -30° C and higher levels than these degrades the quality.

Lakshmi *et al.* (2011) has enlightened the overall economic merit for the fitness, quanitative and qualitative traits and hybrid vigour, the new hybrid is adjudicated as most promising for commercial exploitation under high temperature and low humidity conditions. Malik *et al.* (2005) reported that genotypes Jam 21and CSR4 hold promise for commercial exploitation during both spring and summer seasons. Malik and Reddy (2010) reported higher silk gland weight and somatic index when silkworm treated with linoleic acid. Maqbool *et al.* (2015) reported that the genotypes Sheiki II, Pampore-5, J122, Meigitsu, 14M, NJ3, NB18, CSR2and CSR4 were significantly superior to the check breeds in several subsets of traits in both spring and summer. These genotypes can further be tested over seasons/years to confirm the stability of their performance.

The change in temperature along with relative humidity has pronounced effect on moulting period (Mishra and Upadhyay, 2002). Muniraju *et al*. (1999) reported the effect of temperature on leaf-silk conversion in silkworm that low temperature (26°C) throughout the rearing period favoured higher silk conversion with better survival in bivoltine silkworm. The temperature above 43° C may be lethal to all developmental stages of the multi voltine race, strains *C. Nicini* of *Bombyx mori* (Oman and Karumathil, 1995). Rise in temperature from 24 -36 °C produces considerable decline in larval duration which may affect the lateral stages of the life cycle of Bombyx mori L. Low temperature is always better than high temperature with reference to productivity of silkworm and larval duration for different instars (Pandey *et al.,* 2006 & 2008). Maintaining temperature at 24ºC reduced larvae mortality and increase pupa weight and cocoons (Pal *et al*., 2014).

High temperature during stage end of development accelerate their growth and shortened lifespan. On the other side, low temperature inhibits the growth of larvae and prolong their lifespan. Significantly greater growth and development of silkworm larva and silk gland obtained under the optimum environmental conditions of 25 °C and 70% RH; this may help to improve the productivity of sericulture (Rahmathulla *et al*., 2004 & 2013).

Ram *et al.* (2016) has mentioned in his paper that the exact effect of climate change on soil health and sericulture industry is based on the temperature which may rise from 0.5 - 4.0°C in the various part of the country in next few decades from the accumulation of anthropogenic greenhouse gases in the atmosphere, which may change practices and economy of sericulture drastically in temperate region and marginal or beneficial effect in tropical region in India.

Ramachandra *et al.* (2001) reported that the rate of spinning of silkworm larva (*Bombyx mori* L) was slow at 22^0 C and fast at 38^0 C. The time taken for completion of cocoon was longest at 98 ±2% and least at 40 ± 2% RH. Good quality cocoons were spun at 22°C and 65±5% RH, hence it would be advantageous to maintain this temperature and relative humidity at the time of cocoon spinning in silkworm. Ramesha *et al.* (2009) observed that economically important genetic traits of silkworm are qualitative in nature and that phenotypic expression is greatly influenced by environmental factors such as temperature, relative humidity, light and nutrition influenced.

Reddy Vemananda *et al,* (2001) studied that at high temperature sterility is induced in different races of silkworm. Saha et al. has observed the effect of adverse climatic conditions for successful bivoltine cocoon crop. Sekarappa *et al.* (2009) has reported that the temperature requirement during the early instars are high and the worms feed actively, grow very vigorously, and lead to high growth rate. Such vigorous worms can withstand better even at adverse conditions in later instars.

Shirota (1992) demonstrated that silkworms were more sensitive to high temperature during the fourth and fifth stages. Siddiqui *et al.* (2005) observed that high temperature affects nearly all biological processes including the rates of biochemical and physiological reactions ultimately affecting the quality and quantity of cocoon crops. The silk cocoon production is determined by various factors including environment and genotype of the silkworm. Singh (2013) was observed that late stage larvae exhibited maximum tolerance as compared to the adult moths and the eggs, He also observed that exposure to 17° C and 33 °C was tolerated equally whereas temperature of 43 °C proved to be lethal. Singh and Mavi (1987) has showed in his experiment that the average temperature between 23.9 to 25.8 °C along with 90.9% relative humidity has been proved to be favourable for the best survival of Bombyx.mori larvae. Suresh Kumar *et al.* (2001) has discussed the role of different environmental factors like temperature affecting the growth, survivability, productivity and disease incidence in silkworm. Suresh Kumar *et al.* (2011) has been successful to develop bivoltine double hybrid tolerant to high temperature and high humidity conditions of the tropics. The breeding process as well as the comparative performance of the new hybrid with the already developed double hybrid is also discussed in detail. The study has resulted in the development of bivoltine double hybrid tolerant to high temperature and high humidity conditions of the tropics.

Tazima *et al.* (1995) observed that high temperatures can eventually affect the quality or quantity of cocoon crops in the silkworm and subsequently silk produced. Venturia has studied the effect various environmental factors on growth of silkworm larva. Venugopal Reddy *et al.* (2015) revealed that the larval length varies from 5.00 to 7.43 cm of fifth instar from day 1 to day 6 under ideal conditions i.e. 80-85 % humidity and 25-26°C.

Vijaya Kumari *et al.* (2001) has demonstrated the influence of temperature and humidity during rearing time and its role on disease incidence.Wanule Dinesh *et al.* (2013) showed that adult of *B. mori* were died when kept at 40± 5°C and unable to lay eggs, at 30±1 °C they lay least number of eggs and died within 72 hours. At 10 ± 1 °C they exhibit diapauses mechanism and delayed in egg laying showed higher number of egg lying and found live on the day15th of termination of experiment. No change in temperature cause normal reproduction behavior and laid highest number of eggs and died after seven days. Willmer *et al.* (2004) stated that high temperature affects nearly all biological processes including the rates of biochemical and physiological reactions. Silkworms were more sensitive to high temperatures during the fourth and fifth stages. As suggested by Rahmathulla (2012) the optimum temperature required for various larval stages of silkworm are shown in the table 1.

Table-1- The optimum temperature required for various larval stages of silkworm.

Stages	Temperature range
I	27^0 - 28^0C
II	$26\ ^0$- 27^0C
III	26^0 - 27^0C
IV	24^0 - 25^0C
V	23^0 - 24^0C

Conclusion:

The purpose of this study is to obtain recent data to get an idea of performing different trials of experiment on various larval stages of silkworm Bombyx. mori. It imparts not only augment current knowledge about thermotolerance in silkworm larvae of multivoltine and bivoltine hybrids, but also provide valuable information about the identification of thermotolerant hybrids of mulberry silkworm larvae. We conclude from this review that survival rate and yields of mulberry silkworm depend on temperature. There is a negative correlation between temperature and the various parameters of silkworm larvae. The present study indicates that greater growth and development of silkworm larva obtained under the optimum environmental conditions of 22 -26°C and 75-85% RH, thus help to improve the productivity of sericulture. Generally as the temperature increases, larval weight decreases. High temperature did not favour the productivity and tends to the withering of mulberry leaves which were fed to the silkworms, thereby reducing the feeding quantum. But high temperature accelerates the growth rate leading to poor cocoon quality.

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