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[Review]

Effect of rearing season, host plants and their interaction on economical traits of tropical tasar silkworm, *Antheraea mylitta* Drury- an overview

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Abstract

Tropical tasar silkworm, *Antheraea mylitta* (Lepidoptera: Saturniidae) is a polyphagous silk producing forest silkworm of commercial importance in India. Forest dependent people rear its larvae on different forestry host plants twice or thrice in a year for small household income. Larvae of *A. mylitta* feeds on many forest tree species, but always show a great degree of selectivity as a function of its behavioural responses to physical structure and chemical features of the host plants. Cocoon crop of *A. mylitta* is influenced by heterogeneity of tasar food plants and climatic conditions of the habitat. The role of host plants, temperature, humidity, rainfall, photoperiod and climatic variables on the growth and development of insects have clearly been demonstrated. This article entails an in-depth analysis on ecological and nutritional aspects of *A. mylitta*, which may provide selective information to researcher and forest managers, who are particularly associated with livelihood improvement of the poor people in forested area through location specific forest insect industry.

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Introduction

The exploitation and commercialization of tropical tasar silkworm, *Antheraea mylitta* originated in India, and the tribals of Chotanagpur are their inventers. Tropical tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae) is a polyphagous silk producing insect of commercial importance, widely distributed in moist deciduous, semi evergreen, dry deciduous and tropical dry deciduous forests in India (Rao, 2001). Poor people in forest fringe area commercially rear the larvae of this silk producing insect on different forest tree species for small household income. The tasar culture provides livelihood to 1.65 lakh tribals in Jharkhand, Chhattisgarh, Odisha, Madhya Pradesh, West Bengal, Uttar Pradesh, Maharashtra, Bihar, and Andhra Pradesh states (Reddy, 2010) with total raw silk production of 1724.97 MT (CSB, 2013). Creation of rural employment, alleviation of poverty and elevation of socio-economic status of tribals are the unique feature of Indian tropical tasar culture (Suryanarayana and Srivastava, 2005; Manohar *et al.,* 2009).

In nature, *A. mylitta* has opted forty-five forest tree species as primary, secondary and tertiary food plants (Srivastav and Thangavelu, 2005) and have built up sixty-four different forms of ecological populations called ecoraces (Rao *et al.*, 2003). The polyphagous nature of the tasar silkworm is a boon for many rural tribal in central

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India, as their livelihood are linked with the collection and sale of nature grown tasar wild cocoons (Nayak *et al.,* 2000; Hansda *et al.,* 2008; Ojha *et al.,* 2009). *A. mylitta* completes its life cycle twice or thrice in a year depending on the biotic and abiotic factors, and accordingly the race is recognised as bivoltine (BV) or trivoltine (TV). Daba (BV) and Sukinda (TV) are the most commercially exploited ecoraces of *A. mylitta*, which is a prerogative of India. *A. mylitta* in its natural habitat hatches and multiplies in favourable season and synchronises with available forestry host plants and develops an appropriate voltinism according to the prevailing agro-climatic conditions (Thangavelu, 2000). *A. mylitta* eat out its total food requirements during its larval stages and accumulate sufficient food energy to survive non-feeding pupal and adult stages. Depending upon the altitude of the place of occurrence, the life cycle of the tasar silk moth may be univoltine, bivoltine, trivoltine, or multivoltine (Nayak and Guru, 1998a). Bivoltine *A. mylitta* has two annual lifecycle, the first being the seed crop (July-August) having shorter larval span, yielding non-diapausing cocoons; while the subsequent one is called commercial crop (September-December) with longer larval span, yielding cocoons with thicker shell with prolonged pupal diapause period of 6-7 months (Suryanarayana and Srivastava, 2005).

The cocoon of *A. mylitta* shows considerable variation in their colour, size, shape, pupal weight, shell weight, and the silk output (Jolly *et at.,* 1974, 1979). Such variations in the cocoons mainly occur due to the variation of race, climatic conditions, food plants, altitude etc. (Nayak and Guru, 1998b). Several workers have reported that host plants influence the weight gain by larva, survival percentage, growth index, pupal weight, adult emergence, and fecundity (Basu, 1944; Srivastava, 1959; Thobbi, 1961; Pandey *et al*., 1968; Singh and Byas, 1975; Dubey *et al*., 1981). All these workers mentioned in their studies that lesser larval developmental period, more larval weight gain, and higher percentage of adult emergence are the major criteria to determine the superiority of a host plant on other. There have been a number of studies on the biological parameters of different insects on different host plants under different environmental conditions (Etman and Hooper 1979; Bae *et al.,* 1997; Guan and Chen 1999; Ahmad *et al.,* 2007).

Insect host plant interaction- a historical preview

The foundations for the study of insect-host plant relationships were clearly defined by Charles T. Brues in 1920's (Brues 1920 and 1924). Brues used three categories of phytophagous insects, which are being still used. Insects, which feed on a single host plant species, Brues called them monophagous, while those insects that feed on a definite few host plant species, he called oligophagous and for those insects, which feed on a wide variety of host plant species, was called polyphagous. *A. mylitta* is a polyphagous insect and has opted forty-five forest tree species as primary, secondary and tertiary food plants (Srivastav and Thangavelu, 2005).

The knowledge regarding insect-host plant relationship has highlighted the food preference by insects with regard to its nutritional value. Long back, Hiratsuka (1920) carried out a comprehensive quantitative study on digestion and utilization of *Bombyx mori* on mulberry leaf. Thereafter, Evans and Goodliffe (1939) worked on utilization of food by insects. Earlier studies on utilization of food by insects were not clearly described because several indices were used to report more or less the same measurement in different names (Hopkins, 1912; Evans and Goodliffe, 1939; Crowell, 1941; Smith, 1959; Mathur, 1967; Saxena, 1969). Study of the effects of host plants on the biology of insects is important in understanding the host suitability under different environmental condition (Xue *et al.,* 2009).

First, Thangavelu (1992, 1993) emphasised the need for conservation of wild sericigenous insects in Himalayan states of India. He highlighted the importance of systematic research on various aspects of non-mulberry silks, because studies on the host plant interaction of sericigenous insects are necessary for better management and development of the sericulture industry (Sinha *et al.,* 2000). Siddiqui *et al.* (2006) stressed that conservation of *A. mylitta* in different pockets of forest under different geographical and climatic area is necessary and some of the commercial ecoraces of *A. mylitta* viz., Raily, Modal, Bhandara, Sukinda, Daba and Andhra local are being maintained in different forest areas of central India; but it is lacking in Uttarakhand. As suggested by many sericulturists, the specific climatic and geographical pockets in India can serve as new natural habitat for forest silkworm (Tripathi *et al.,* 1988b; Sinha *et al.,* 2000; Naik *et al.,* 2010; Reddy *et al.,* 2010). Deka and Kumari (2013) stressed that in order to increase the raw silk production of *A. mylitta*, exploitation of all the ecoraces and their food preferences should be established through comparative study of the effects of different food plant species under new agro-climatic condition.

Cocoon crops of *A. mylitta* are influenced by the season, host plants and their interactions (Venugopal and Krishnaswami, 1987). Over generations, *A. mylitta* have adapted to different environmental conditions and different ecoraces with phenotypic variations are reported from India, out of which only Daba and Sukinda eco races are mainly contributing for country's tasar raw silk (Rao *et al.,* 2004; Hansda *et al.,* 2008; Ojha *et al.,* 2009; Reddy *et al.,* 2010). *A. mylitta* is commercially exploited, only in India.

During the last fifty years, many articles have been published on insect-host plant interactions of Daba ecorace of bivoltine tropical tasar silkworm, *A. mylitta*, and all these studies were mainly carried out on *Terminalia arjuna*, *T. tomentosa*, and *Shorea robusta* in traditional tasar silk producing states of India, viz., Jharkhand, Odisha, Chhattisgarh, Andhra Pradesh and West Bengal.

Major studies on *A. mylitta* includes: morphology of the larva (Narasimhanna and Jolly, 1969; Narasimhanna *et al.,* 1969), influence of temperature and photoperiod on termination of pupal diapauses (Jolly *et al.,* 1970), effect of habitat and food (Prasad, 1980), effect of refrigeration on hatching (Dash *et al.,* 1988; Nayak and Dash, 1989), growth and leaf yield of Asan and Arjun (Nayak *et al.,*1988, 1998), and larval energetic in different food plants (Dash and Dash, 1989; Dash *et al.,* 1996; Dash, 2001), occurrence of deformed cocoons (Dash and Nayak, 1990), rearing performance of *A. mylitta* with artificial diet (Akai *et al.,* 1991), effect of food plants on cocoon crop performance (Dash *et al.,* 1992, 1994), preservation of seed cocoons (Kapila *et al.,* 1992), voltinism (Nayak *et al.,* 1992), rearing and cocooning (Ojha *et al.,* 1994), abnormal tasar cocoons (Mohanty and Behera, 1998), effect of starvation on larva (Dash *et al.,* 1988), cocoon and post cocoon studies (Rao and Samitha, 2000), bioenergetics during diapauses (Satpathy, 2003), effect of outdoor cocoon preservation (Chakrabarty *et al.,* 2003), reassuring livelihood functions of the forests to their dependents (Bhatia and Yousuf, 2013a), forest insect industry in collaborative forest management (Bhatia and Yousuf, 2013b), assessment on climatic suitability of Dehradun to introduce forest based rearing of *A. mylitta* in Uttarakhand (Bhatia and Yousuf 2013c) and parasitic behaviour of *Xanthopimpla pedator* on *A. mylitta* (Bhatia and Yousuf 2013d)

The following highlights of the literatures, which are particularly relevant to the effect of rearing season, host plants and their interaction on biological and economical parameters of tropical tasar silkworm *Antheraea mylitta,* are given as under.

Effect of rearing seasons on biological and economical traits of insects, especially *Antheraea mylitta* Drury

Season indicates the inter-annual variation in temperature, humidity, sunshine, rainfall, etc. of a particular place, which is governed by different geographical parameters (Murthy *et al.,* 1996). Studies have shown the importance of seasonal variations in biology and development of insect (Odum, 1983; Ouedraogo *et al*., 1996). Insects are cold-blooded (Poikilothermic) organisms, so their body temperature is more or less same as that of their surrounding microenvironment. Temperature influences everything that an organism does (Clarke, 2003), humidity affects embryonic development (Tamiru *et al.*, 2012), and rainfall affects both.

Environmental temperature, being the major abiotic factor, regulates the body temperature of caterpillar that determines the rates of feeding, fecundity, and mortality (Casey, 1981; Wellington *et al.*, 1999). Temperature is probably the single most important environmental factor that influences behaviour, development, survival, reproduction, and geographical distribution of insects (Benchamin and Jolly, 1986; Shiva Kumar *et al.,* 1997; Petzoldt and Seaman, 2013). All the insect species has their own choice of temperatures for usual growth and very high temperature slows down the growth that may leads to developmental malfunction, such as larval ecdysis and adult emergence (Chapman, 2002). Temperature regimes and different levels of relative humidity are known to play an important role in the life cycle of insect and its adaptability to the local climate (Tamiru *et al.,* 2012). Some researchers believe that the effect of temperature on insects largely overwhelms the effects of other environmental factors (Bale *et al*. 2002) and that is why, most of the insect's forewarning and forecasting models are based upon accumulated degree-days from a base temperature and bio-fix point. Yamamura and Kiritani (1998) estimated that with a 2°C rise in temperature, insects might experience one to five additional life cycles per season. Most researchers seem to agree that warmer temperatures result in more types and higher populations of insects (Coviella and Trumble, 1999; Hunter, 2001; Hamilton *et al.,* 2005). It has been reported that the temperature has highly significant effects on all developmental parameter of insect than humidity and rainfall (Bhat and Bhattacharya, 1978). Developmental time of an insect is inversely related to temperature (Tamiru *et al.,* 2012). Among the various environmental factors that influence the silkworm cocoon crops, the most important are temperature followed by humidity. Temperature has a direct effect on the growth, development and physiological activity, nutrient absorption, digestion, blood circulation, respiration etc. Temperature plays an important role in egg hatching, larval growth and quality of the cocoons produced, adult fertility etc. With the increase in temperature, the larval growth and development is accelerated resulting reduction in larval duration, cocoons of lower weight and quality, while at low temperature growth and development is slow leading to prolong larval period, abnormal growth and sensitivity against several diseases (Singh *et al.*, 2009).

Second abiotic factor that has significant impact on the performance of insects in terrestrial environments is humidity. Humidity interacts with free water availability and with the water content of the food plants. There is no limiting range of humidity and most insect can develop at any humidity provided they are able to control their water balance (Hunter, 2001). Humidity shows mostly indirect effect on growth and development. Under too dry conditions, the leaves wither very fast and become unsuitable for insect feed, resulting in retarded growth of larvae, which makes them weak and easily susceptible to diseases and other adverse conditions. During egg incubation, it is important that humidity should be maintained at 80% on an average for normal growth of embryo. If humidity falls below 70% during incubation, it affects hatching (Singh *et al.*, 2009). Studies have also indicated the combined effects of temperature and relative humidity (Getu, 2007; Tamiru *et al.,* 2012).

Rainfall alters the functioning of microhabitat, which along with soil and other environmental factors affects foliage and water levels, which consequently affect on performance of insect (Mattson and Haack, 1987). Chemically the variation from succulent leaves to mature is so large that it may halve the growth rate of Lepidopteran larvae (Rausher, 1981).

Fluctuation in temperature, humidity and other seasonal factors prevents insects from attaining their physiological potential life history performance (Slansky and Scriber, 1985). However, forest insects display a remarkable range of adaptations to changing environments and maintain their internal temperature (thermoregulation) and water content within tolerable limits, despite wide fluctuations in their surroundings, because impact of temperature is modified by habitat and other physical conditions (Singh *et al.*, 2009). Temperature, humidity, air circulation, gases and photoperiod etc. shows a significant interaction in their effect on the physiology of silkworm depending upon the combination of factors and developmental stage affecting growth, development, productivity and quality of silk (Singh *et al.*, 2009). Seasonal and environmental interaction have great role to play on the expression of commercial characters of *A. mylitta* (Siddiqui *et al.,* 2006).

The potential phenotypic expression of a genotype desires suitable environment (Srivastava *et al.,* 2004; Mulder and Bijma, 2005) and the environment being exogenic factor influences the expressivity of gene by generating different phenotypes under different environments (Jong and Bijma, 2002; Zhao *et al.,* 2007; Kumar *et al.,* 2008). The variations in climate, nutrient status, feeding duration and larval crowd along with environmental stimuli influence the insect body size and its biological success (Davidowitz *et al.,* 2004; Miller, 2005; He and Wang, 2006). Natural population is often heterogeneous and undergoes continuous selection by the local environmental fluctuations and by geographic transition (Lints and Gruwez, 1972; Masaki, 1978).

Green *et al.* (1996) mentioned that the ecological range of most organisms especially the ectothermic animals is determined by the available food, ambient temperature, humidity etc. According to Krishnaswami (1978), the silkworm rearing seasons are broadly classified as spring, summer, and rainy crops, based on the temperature, humidity, and rainfall. Identification of best rearing season is a prerequisite for the success of Seri-business in a given area. Sengupta (1988) opined that the success of sericulture in Japan could be attributed to the identification of the suitable rearing seasons. Jayswal *et al.* (1990) reviewed the interaction between genotype and environment for economic traits in hybrid combinations of silkworm and asserted that environment causes effective restrain on biological characters of silkworm like, effective rate of rearing (ERR), single cocoon weight, single shell weight, and shell ratio and filament length. Shiva Kumar *et al.* (1997) also concluded that the quality of food and rearing temperature, largely influence silkworm productivity. The phenotype *A. mylitta* is the result of interaction between genotype and environment in which it develops (Sengupta, 1991). *A. mylitta* expresses divergent phenotypic characters in response to varying ecological and climatic conditions (Lokesh *et al.,* 2012). It has been reported that variations in the fluctuations of temperature prevent insects from attaining their physiological potential performance (Singh *et al.*, 2009), which involve changes in the consumption and utilization of food, rate and time of feeding behaviour, metabolism, enzyme synthesis, nutrient storages and other physiological and behavioural process (Slansky and Scriber 1985).

Sinha and Chaudhury (1992) asserted that phenological parameters of *A. mylitta* are mostly dependent on the ambient temperature and relative humidity available during the period of larval and pupal development; hence, the developmental pattern of *A. mylitta* is season specific. Dash *et al.,* (1994) found better cocoons crop performance of *A. mylitta* in winter crops than those of rainy and autumn seasons. Srivastava *et al.* (1998) reported that environmental conditions are the main cause of variability in *A. mylitta,* because the fecundity, hatchability, cocoon weight, shell weight, absolute silk yield, filament length, denier, and sericin percentage varied significantly during different rearing seasons.

Sengupta *et al.* (2002) found that all the commercial characters of Daba ecorace (BV) of *A. mylitta* viz., cocoon weight, shell weight, SR%, cocoon volume, filament length, denier, average silk recovery percentage and silk yield/1000 cocoons was significantly higher in second crop rearing than the first crop. Similarly, Deka *et al.* (2011) found better performance of Daba ecorace (TV) of *A. mylitta* in spring season followed by autumn, winter, and summer season.

Dash *et al.* (1994) assessed cocoon crop performances of the Indian wild tasar silkworm, *Antheraea paphia* on different food plants viz., *T. tomentosa*; *T. arjuna* and *Shorea robusta* during different rearing seasons in agro-climatic condition of Durgapur, Odisha. They evaluated cocoon crop performances in terms of effective rate of rearing (ERR); total cocoons yielded, cocoon weight, pupa weight and shell weight for each category of food plant in each rearing season. Their results showed that cocoon crop performances were better in autumn crop (Sept.-Oct.) than in rainy (July-Aug.) and winter (Nov.-Dec.) season. The larval form of tropical tasar silkworm can invade diverse habitats and can utilise food sources of many forest tree species and can feed and grow at phenomenal rates (Rath *et al.,* 2004). However, under suboptimal environmental conditions, *A. mylitta* D. larvae can survive for delayed period at much slower growth rates (Jolly *et al.,* 1974). The abiotic and biotic factors of the environment during different seasons greatly influence the life history features of the *A. mylitta* in the form of larval weight, cocoon weight, pupal weight, shell weight, shell percent, percent emergence, percent coupling, adult longevity, fecundity, percent hatching and reelability of the silk (Jolly *et al.,*1974; Thangavelu and Sahu, 1986; Nayak and Dash, 1989; Chaoba Singh *et al.,* 1991; Yadav *et al.,* 1992; Nayak *et al.,* 1993; Zhu *et al.,* 2000; Chen *et al.,* 2002; Seema *et al.,* 2004).

Due to outdoor mode of forest based rearing, the silkworm larvae of *A. mylitta* may suffer heavy loss due to predator, parasitoid, and diseases. It is estimated that on an average, 30% of total crop loss due to various diseases is observed per year (Sahay *et al.,* 2008). Silkworm diseases form major constraint in realizing full crop yield (Kumar and Naik, 2011).

Tanaka (1951) remarked that the rainy season is unsuitable for rearing of *B. mori* due to high RH and changing temperature. Kishnaswami *et al.* (1973) reported that temperature and RH exceeding 20-26^{o}C and 60-70%, respectively, affected the cocoon quality of *B. mori.* Jolly *et al.* (1974) remarked that heavy rainfall disrupted spinning resulting in inferior cocoons. Sarkar (1980) stated that sudden fluctuation in temperature is harmful to rearing of *Philosamia ricini* worms. Ullal and Narasimhanna (1987) reported that high temperature followed by severe weather fluctuation resulted in poor cocoon quality in *B. mori*. Barah *et al.* (1988) studied variation in cocoon characters of *A. assama* during different season and found that cocoons produced in different seasons are not uniform in their commercial character. It was found by Kar *et al.* (1998) that the commercial traits of eri silk moth, *Samia ricini* such as cocoon, shell and pupal weights varies significantly during summer and winter seasons. Naik *et al.* (2010) found significant difference in growth index of eri silkworm with respect to host plants, seasons, and their interaction. Rahmathulla and Suresh (2012) concluded that *B. mori* made physiological adaptations during summer season to withstand suboptimal condition. Tamiru *et al.* (2012) found that temperature, relative humidity (RH) and their interaction significantly affected the developmental time, adult longevity, and potential fecundity of *Chilo partellus.*

Information on the effect of season and rearing condition on different parameters of rearing has also been reported on other groups of insects (Cunnington, 1985; Johansen, 1997), in mulberry silkworm (Krishnaswami *et al.,* 1971a and 1971 b; Mathur *et al.,* 1995) and in non-mulberry silkworms, (Choudhary, 1981; Sinha and Chaudhury, 1992; Sahu, *et al.,* 1998; Situmorang, 2002; Das *et al.*, 2004).

Host plants' nutrients and its effect on biological success of *A. mylitta*

The suitability of a host plant to an insect depends upon the presence of balanced nutrition in the plants for proper growth and development in insect. Beck (1956) suggested that nutritional requirements of an insect species are a chemical factor essential to adequacy of ingested food. Insect larva of non feeding adult insects is a voracious feeder, hence their growth rate, developmental time, final body weight, survival and reproduction traits are influenced to a great extent not only by the climate and rate of feeding but also equally by the food quality (Rath *el al.* 2006). That is why maximum potential fitness of any insect is only possible when the larva obtain adequate amount of necessary nutrients in a suitable relative balance (Slansky and Scriber, 1985). As nutrients can influence all aspects of insect performance, therefore, larvae to achieve maximum potential fitness must ingest adequate amount of necessary nutrients (Rath, 2005). Matsumara *et al.* (1958) reported that out of the various factors responsible for success of silkworm cocoon, leaf quality stood first by contributing 38.2%.

Many plants are known to synthesise a variety of chemicals, which are not an essential ingredient in plant metabolism and presumably, they are stored in any convenient place within the plan structure. These kinds of substances have been called secondary metabolic products (Price, 1997), which can be utilised by the insects as cues to identify the plant for feeding and breeding purposes. It would appear that, aside from the sugars and perhaps some salts (Butler, 1940), insects are guided to their natural foods by the tastes and odours of various chemical substances, which in themselves have no nutritive value (Uvarov, 1928).

The ability of insect to discriminate the nature of food is largely governed by the chemicals present as plant constituents. In general, the nutritional factors do not directly decide the acceptance or rejection of food plants. On the other hand, some nutrients like amino acids and sugars may act as feeding stimulants (Dethier, 1966). Dadd (1960) opined that instances of poor growth in insects might not be due to the nutritional inadequacy of the diet but to a low rate of intake due to the absence of a non-nutrient phagostimulant.

The Lepidopteran requires a number of organic compounds viz., carbohydrates, fats, lipids, vitamins, steroids and amino acids as nutrients. In the course of digestion and respiratory pathways, the energy is released from these organic molecules through a series of physiological and biochemical changes (Jolly *et al.,* 1974). The requirement of nutrition in sericigenous insects is highly specific for their optimal physiological status and sustainable productivity (Mohanty, and Mittra, 1991; Sinha *et al.,* 2007a). Leaf quality, production rate and gestation period of different forestry host plants influence the commercial feasibility of *A. mylitta* (Reddy *et al.,* 2010). The foliar constituents in a number of tasar food plants have been analysed for moisture, crude fibre, total minerals, reducing sugar, total sugar, starch, total nitrogen, and crude protein (Jolly *et. al.,* 1979; NISCAIR, 1976; Puri, 1994; Sinha and Jolly, 1971; Sinha and Jolly, 1971)

The availability of essential nutrients in tasar food plant is vital for successful life cycle, cocoon quality, metamorphosis to moth stage and reproductive activity of *A. mylitta* (Pattanayak, and Dash, 2000; Reddy *et al.,* 2009). The leaf nutrition of tasar food plant can enhance the effective rate of rearing (ERR), because feed quality has direct correlation with health and growth of larvae for better crop yields in terms of cocoon and shell weights, silk ratio, and silk filament (Dash *et al.,* 1992; Yadav and Mahobia, 2010). Significant positive correlation has been reported between chemical compositions of mulberry leaf and larval health as well as cocoon characters (Venkataramu, 1986). Benchamin and Jolly (1986) also reported that growth and development of the larvae and subsequent cocoon crop production of silkworm larvae depend on leaf quality, especially the nutrient contents. The quality of the leaves of host plant varies significantly with factors such as soil fertility, agronomical practices, planting system and environmental condition (Bongale *et al.,* 1991; Datta, 1992).

The water content of mature leaves provides a useful quantitative index of plant growth form (Scriber and Slansky, 1981). Water forms a large proportion of insect tissues and survival depends on the ability to maintain water balance in the body. The water content in insects ranges from less than 50% to more than 90% of the total body weight and there may be much variation within the same species even when reared at identical conditions (Mathur and Lal, 1994). Rath (2010) found that the dietary water is very closely associated with number of feeds/day that plays a crucial role in the growth in *A. mylitta* as in other herbivorous larval Lepidoptera (Slansky and Scriber, 1985). It was also found that consumption of food of lower water content could result in significant reduction in relative growth rate and efficiencies of conversion of digested food (Reese and Beck, 1978; Timmins *et al.,* 1988). Benchamin and Jolly (1986) reported that silkworm larva prefers to consume the leaves that contain high moisture and less dry matter. Periaswamy (1994) reported that water content of leaf play a significant role on food utilization and growth in phytophagous insects. Basavarajappa and Savanurmath (1997) observed that on feeding over matured and wet leaves enhanced the incidence of virosis disease and cocoon melting. Vage and Ashoka (1999) reported that when fifth instar larvae fed with tender shoots up to 3 days followed by matured shoots marked better values of cocoon characters; however, Elumalai *et al.* (2001) reported that coarse leaves feeding enhance the most of the economic characters of bivoltine pure races in mulberry silkworm.

It has been reported that the rearing performance of the *A. mylitta* has a positive correlation with the moisture content of the leaf (Krishnaswami, 1978; Thangamani and Vivekanandan, 1984). High moisture content in the leaves has favourable effects on the palatability and assimilability of nutrients that serves as criteria in estimating the leaf quality (Parpiev, 1968). Narayanan *et al.* (1967) also revealed that tender leaf having higher nutritional value favours growth of the silkworms, and then increasing the cocoon characters. Rashid *et al.* (1993) reported that growth rate and digestibility of any insect depends on nutritional quality and water content in its food.

Nitrogen is very important for proper growth and development of insects. Nitrogen fertilization of plants generally results in an increase in leaf water as well as nitrogen content, and this creates a situation when insect infestation increases Scriber (1982). The maximum performance values of foliage-chewing larvae are strongly correlated with the contents of water and nitrogen in leaves (Slansky and Scriber, 1985). Rearing performance of *A. mylitta,* larvae are strongly co-related with the water and nitrogen content of the leaves (Prasad *et al.,* 2004). Scriber and Slansky (1981) investigated the influence of food quality on larval performance by comparing performance values of similarly aged larvae of several insect species raised under similar photoperiod, temperature, and humidity. They indexed food quality by leaf water and nitrogen contents and concluded that differences in food quality (as indexed by leaf water and nitrogen) may be due to differences between food species or within a food species due to changes in growth conditions or with the seasonal aging of leaves.

Proteins are the ubiquitous organic nitrogenous compound in the foodstuff of silkworm larvae, which are involved practically in all the structure and function of the cells (Chapman, 1998). Slansky (1982) reported that protein is required not only for adult maintenance but also to supply the energy and nutrients for provisioning the eggs and egg production in insects. *A. mylitta* is a tool to convert leaf protein of food plants into silk. Sinha *et al*. (1998) found that the crude protein content was significantly higher in *T. alata* (12.17%) and lowest in *S. robusta* (10.80%). Deka and Kumari (2013) estimated the protein content in the leaves of *T. tomentosa* (15.94 mg/g); *T arjuna* (13.20 mg/g); *T. bellirica* (11.60 mg/g); *T. chebula* (12.23 mg/g) and *L. speciosa* (13.37 mg/g) fed to the larvae of *A. mylitta*. They found a positive correlation between protein content of the leaves with larval, cocoon, pupal and shell weight of the *A. mylitta*.

The previous studies conducted by Narayanan *et al.* (1967), Sudo (1981), Bongale *et al.* (1991) and Krishnaswami *et al.* (1970) proved that tender leaves are having more water as well as protein content. This protein content of the tender leaves is absorbed by the silkworm epithelium tissue of the gut and is transferred to the body matter as well as in to the cocoon formation. Machii and Katagiri (1991) reported that mulberry varieties containing higher contents of protein in leaves have higher production efficiency of cocoon shell. It was found by Krishnaswami (1978) and Singhvi and Bose (1991) that the *Bombyx mori* larvae fed with protein rich mulberry leaves showed significant enhancement in its larval, cocoon and shell weight.

Carbohydrates occupy a very important place especially in case of phytophagous insects. It is the most commonly distributed and widely occurring compounds in plants with enormous variations in their quantity and quality (Sinha *et al.,* 1998). Carbohydrates are utilized by the silkworm as an energy source and for synthesis of both lipids and amino acids. The degree of fat body glycogen and haemolymph trehalose is also dependent on the carbohydrate contents in diet of silkworm (Ito, 1967). Sinha *et al.* (1998) found significantly higher quantity of total sugar in *T. tomentosa* (7.9%) followed by *T. arjuna* (5.7%) and *S. robusta* (5.3%).

Carbohydrate, protein, and lipid are known to be the main sources of energy at the time of larval-larval, larval-pupal, pupal-adult transformation (Krishnaswami, 1978; Thangamani and Vivekanandan, 1984). Availability of these nutritional components has been reported to be on higher side in *T. alata*, *T. tomentosa, T arjuna* and *L. speciosa* than *T. bellirica*, *T. chebula* and *L. tomentosa* (Agrawal *et al.,* 1980; Sinha and Jolly, 1971; NISCAIR, 1976), which improves the performance of larval and cocoon character of *A. mylitta* accordingly, on these host plants (Sinha *et al.,* 1986).

Further, higher crude fibre content in the leaves of forestry host plants of *A. mylitta*, is known to cause detrimental effect on silkworm nutrition (Krishnaswami, 1978). Crude fibre is the ash free material largely composed of cellulose and lignin, but cannot be digested by the silkworm larvae. It is not included under nutrient, but its intake along with diet is essential because of regulatory function that helps to maintain the peristaltic movement of the intestine to remove waste products from it (Sinha *et al.*, 1998). Digestibility of Lepidopteran insect is affected by imbalanced diet or high content of crude fibre in the food (Waldbauer, 1964).

Deka and Kumari (2013) estimated crude fibre content in six forest tree species viz., *T. tomentosa* (9.49 %); *T arjuna* (9.86 %); *T. bellirica* (12.32 %); *T. chebula* (12.02 %); *L. speciosa* (10.23 %); and *L. parviflora* (13.46 %). They found that the weight of the matured larvae of *A. mylitta* was maximum on *T. tomentosa* (41.98 g) followed by 37.03 g on *T. arjuna* and 31.91 g on *L.* speciosa. Reduction in fibre content has been established as an advantage for better silkworm crop yield (Vasuki and Basavana, 1969). According to Sinha *et al.* (1998), *T. arjuna* is the best for *A. mylitta*, because it contains lowest quantity of crude fibre (12.82%) than *T. tomentosa* (16.09 %) and *S. robusta* (18.50%). According to Sinha *et al.* (1998) *T. tomentosa* is the best primary food plant for *A. mylitta* followed by *T. arjuna* in respect of the nutritional parameters.

Bose *et al.* (1995) reported that succulent leaves with less fibre and higher mineral contents stimulate the metabolic activities in silkworm, resulting in quantitative improvement of cocoon and silk of *A. mylitta. T. tomentosa* and *T. arjuna* were found superior to *S. robusta* in this respect, because they contain higher percentage of total minerals (8.08% and 6.82% respectively) and lower amount of crude fibre (16.09% and 12.82% respectively). The lowest content of total minerals (3.61 %) and the highest amount of crude fibre (18.50%) were estimated in *S. robusta* (Sinha *et al.,* 1998).

Amino acids are the next most important constituents in silkworm nutrition (Ito, 1967). *A. mylitta* extracts amino acids from the leaves of host plants and produce silk thread (Jolly *et al.,* 1974). Amino acids, obtained from the leaf, are utilized by the silkworm larvae for body growth, development, and cocoon formation. Sinha *et al.* (1998) reported twenty-three amino acids in *T. tomentosa*, *T. arjuna* and *S. robusta*. They found that, though the number of amino acids was the same in all these plants; however, leaves of *T. arjuna* contains higher quantity of total amino acids (61975 μg/g dry leaf powder) followed by *T. tomentosa* (61250 μg/g dry leaf powder). The lowest quantity of total amino acids was found in *S. robusta* (μg/g dry leaf powder). Dhavalikar (1962) reported presence of seventeen amino acids in raw silk of *A. mylitta.*

In a comparative biochemical study of *T. tomentosa* and *T. alata*, Sinha *et al.* (2007b) found that non-hairy leaves of *T. alata* are better than hairy leaves of *T. tomentosa.* The moisture level, total carbohydrate, protein, amino acid and mineral content was found higher in non-hairy leaves than the hairy leaves; however, total fibre content was found higher in hairy leaves of *T. tomentosa* and lower in non-hairy leaves of *T. alata*.

Deka and Kumari (2013) evaluated physiological parameters of different forestry host plants of *A. mylitta* grown under agro-climatic condition of Ranchi, Jharkhand. All the plant species viz., *T. tomentosa, T arjuna, T. bellirica, T. chebula, L. speciosa,* and *L. parviflora* showed significant variation in respect to physiological and biochemical parameters. The highest value of total chlorophyll content of leaf was recorded in *T. tomentosa* (2.69 mg/g) followed by *T. arjuna* (2.59 mg/g) and *L. speciosa* (2.56 mg/g). The total soluble protein content of leaf was found highest in *T. tomentosa* (15.94 mg/g) followed by *L. speciosa* (13.37 mg/g) and *T. arjuna* (13.20 mg/g). Deka and Kumari (2013) argued that the higher value of total carbohydrate content of leaf for *T. tomentosa* (8.54%) followed by *L. speciosa* (8.27%) and *T. arjuna* (8.01%) might be due to the highest value of net photosynthesis rate for these three plant species.

Ponnuvel *et al.* (1996) reported that biochemical constituents of oak (*Quercus serrata*) leaves vary with season. They recorded maximum moisture (71.9%) and crude protein (10.2%) levels in spring season and the levels declined sharply as season progressed. Whereas, minimum crude fibre content (0.9%) was found in spring season and maximum (9.96%) during autumn season.

Jayaramaiah and Sannappa (1998) studied relationship between foliar constituents of Castor genotypes and economic parameters of eri silkworm at UAS, Bangalore. They found that the 1arval duration, weight, survivability, and effective rate of rearing (ERR) were having significant positive relationship with moisture and nutritional content of the host plant. They also found a positive significant relationship between foliar constituents of the host plant and weight of cocoons, pupae, shell weight and shell ratio. Grainage parameters such as moth emergence, fecundity, and hatchability were also showed significant positive relationship with nutritional components of the host plant fed to the eri silkworm.

Suitability of different forest tree species for growth and development of *A. mylitta*

Green plants are the indispensible foundations for all the ecosystems that harness the energy of sun light and by photosynthesis, produce energy rich sugars that are the foods for insects (Waldbauer, 1996 and 2003). The relationship between phytophagous insects and plants is essentially nutritional, because phytophagous insects visit the plant solely to procure food for themselves or for their progeny (Bhattacharya and Pant, 1976). What an insect eats and how much it eats largely determine its ecological role and its economic significance for human beings (Trager, 1953). Moreover, not everything that an insect ingests as food can serve as a source of nutrients (Brues, 1940).

The success of an insect depends significantly upon an optimal diet in both quantity and quality (Hassell and Southwood, 1978), which provides the energy, nutrients, and water to carry out life's activities (Slansky, 1993). The rate of food consumption is influenced by the physical and chemical nature of food and the physiological state of insects (Waldbauer, 1968). The consumption and utilization of food constitute a *sine qua non* for growth, development, and reproduction. The amount, rate and quality of food consumed by a larva influences its performance i.e., growth rate, developmental time, final body weight, dispersal ability, mating success, timing and extent of reproduction, and probability of survival. This influence can also carry over to affect adult performance such as, when a larva suffers reduced growth, it produces a small-sized adult with reduced fecundity. These influences can also carryover to affect subsequent larval performance that effects the quality of offspring produced (Slansky, 1985). Decreased food abundance in nature has an adverse effect on development, metabolism, and reproduction (Slama, 1964; Slansky, 1980; Grabstein and Scriber, 1982).

Lepidopteran larvae consume almost 100% of its total food requirements during its larval stages to accumulate sufficient food energy to tide over the non-feeding pupal and adult stages and to lay eggs (Rath, 2005). It is understood that insects has to reach the intake target to achieve their growth targets in order to attain functional optima and any change in intake and growth target leads to physiological disturbance affecting the performance level of insects (Raubenheimer and Simpson, 1999).

The actual performance of an insect may be reduced below its physiological potential by abiotic and biotic factors, including food quality. The various components of food quality may vary between food species as well as within a species (Soo Hoo and Fraenkal, 1966; Drooz, 1970; Beckwith, 1976; Slansky and Scriber, 1985).

Forestry host plants of *A. mylitta* are known to differ greatly with their nutrient profile that affects its growth and development (Kohli *et al*., 1969; Sinha and Jolly, 1971; Agarwal *et al*., 1980; Sinha *et al*., 1992; Puri, 1994). The quality of leaves has direct influence on the health, growth, and survival of silkworm (Sinha *et al.,* 1986). Better, the quality of leaves, greater are the possibilities of obtaining good cocoon crops. Therefore, the selection of the food plants possessing superior nutritive value could be utilised for the healthy development of silkworm for obtaining good silkworm crops (Banerjee *et al.,* 1993).

Food is by far the most complex environmental factor, and the nature of the food determines much of the structure and functioning of insects. The rate of intake of an acceptable food is determined by a complex sequence of processes (Gordon, 1999). The food preference in the insects is governed by the presence of chemicals. They may be secondary substance like glycosides, alkaloids and essential oil as described by Dethier (1947) or sugars Lipke and Fraenkel (1956) and amino acids (Thorsteinson, 1960). According to Bhattacharya and Pant (1976), no single factor controls the acceptance of host tissue by the insect; rather, a combination of the factors like presence or absence of phagostimilants, phagodeterrtants, specific nutrients, toxins, and growth inhibitors decides the suitability of plant species as food materials for insects.

The larval feeding status of any polyphagous commercial insect has impact on food storage and budgeting for biological activities to combat the adverse or to excel during favourable conditions (Chapman, 1998; Chaudhuri, 2003; Hajarika *et al.,* 2003; Saikia *et al.,* 2004; Behmer, 2006; Cizek *et al.*, 2006; Radjabi *et al.,* 2009).Variation in the quality of larval food can have a negative impact in larval weight gain, developmental time and survival as well as adult performances (Scriber and Slansky, 1981; Slansky and Scriber, 1982). The qualitative and quantitative importance of food in connection with negative effects has also been recognized (Kozhanchikov, 1950; Barness, 1955; Legay, 1958, Muthuknshnan and Delvi, 1974; Slansky, 1993).

Studies were undertaken by several scholars to assess the suitability of different host plants for polyphagous insects by offering them several alternative host plants. In their study, parameters like comparative feeding, relative growth rate, larval weight gain, pupal weight, adult emergence, fecundity etc., were the main criterion to determine the most suitable food plant for a polyphagous insect (Basu, 1944; Srivastava, 1959; Dubey *et al.*, 1981). Studying these parameters enable better understanding towards insect host plants interactions and its effect on growth and development (Srivastava, 1959).

The role of host plant is an important factor in regulating insect population (Umbarihowar and Hastings, 2002) as the life cycle characteristics of herbivores may be affected by variation in host plant traits, for example the life history parameters longevity, fecundity and survival may be influenced by the variation in host plant quality (Awmack and Leather, 2002). The development and reproduction of insects correlate directly with the quantity and quality of the food they consume, and the ingestion of this food depends on its availability, acceptance, digestion, and assimilation (Garcia, 1991).

One of the outstanding contributions on consumption, digestion, and utilization of food by silkworm was made by Hiratsuka (1920). Further, Waldbauer (1968) made a significant contribution in bringing uniformity in the use of various growth indices for the study of growth behaviour of insects. The host plants affect silk production of the insect by affecting survival behaviour, rate of quantity of food intake, digestion, and assimilation, which directly influences the growth and development of the silkworm (Krishnaswami *et al.,* 1970; Sinha *et al.,* 2000; Ray *et al.,* 1998; Rahman *et al*., 2004; Saikia *et al*., 2004).

The development and reproduction of *A. mylitta* correlate directly with the quantity and quality of the food they consume, and the ingestion of this food depends on its availability, acceptance, digestion, and assimilation (Rai *et al.,* 2006). The success of tasar silkworm rearing is mainly depends on the accessibility and nutritional status of the food plant, as a consequent silkworm larval rearing could result to higher number of cocoons or the cocoons of superior quality in terms of pupation or silk content (Kumar *et al.,* 2009; Ojha and Panday, 2004; Reddy *et al.,* 2012).

Ahsan and Griyaghey (1973) undertook first systematic study on the effect of different host plants on rearing performance of *A. mylitta* at Central Research and Training Institute, Central Silk Board, Ranchi during 1972-73. They conducted outdoor rearing of *A. mylitta* on seven forestry host plants viz. *T. arjuna* (Arjun), *T. tomentosa* (Asan), *S. robusta* (Sal), *Careya arborea* (Kumbi), *L. parviflora* (Sidha), *Q. serrata* (Oak) and *Z. jujuba* (Ber) in the agro-climatic condition of Ranchi. Their basic criteria for evaluating different host plants was based on the time taken for the first instar larvae of *A. mylitta* to reach pupal and adult stage, per cent pupa formation, adult emergence, gain in body weight and sex ratio.

Jolly *et al.* (1974) reported that the larvae of *A. mylitta* D. differ greatly from their adult form, not only in outer structure but also in musculature, nervous system, tracheation, and many internal organs by feeding on different forestry host plants.

Tripathi *et al.* (1988a) have reared the larvae of *A. mylitta* on nine species of forestry host plants in the agro-climatic conditions of Jharkhand and found that *T. tomentaosa, Shorea robusta* and *T. arjuna* trees support better growth of larvae, leading to formation of cocoons of large size and greator yield of tasar yarn than others forestry host plants, viz*., L. parviflora* and *Sareya arborea*.

Tripathi *et al.,* (1988b) reported that transfer of *A. mylitta* larvae from inferior to superior host plant species result in heavy mortality of the larvae and reduction in cocoon yield.

Dash *et al.* (1992) studied the effect of rearing seasons and different food plants viz. *T. tomentosa, T. arjuna, S. robusta, Z. Jujuba, L. parviflora* and *A. latifolia* on cocoon crop performance of *A. mylitta* under the agro-climatic conditions of Durgapur, Odisha. *S. robusta* appeared uneconomical in terms of total cocoon shell (raw silk) production in spite of a superior cocoon formation. Overall performance of *A. mylitta* was found superior on *T. tomentosa* than all other food plants. The gradation of food plant with regard to performance (total raw silk production) was, in decreasing order of productivity: *T. tomentosa*, *T. arjuna, Z. Jujuba, S. robusta, L. parviflora,* and *A. latifolia.*

Srivastava *et al.,* (1994) tested the efficiency of rearing of muga, eri, and tropical tasar silkworm on different host plants and found that host plant significantly affected the rearing and grainage traits of all the non-mulberry silkworms. Their observations with regard to silk ratio and number of eggs per laying of *A. mylitta* reveal that *S. robusta* and *Zizyphus jujuba* fed cocoons had higher silk ratio and number of eggs per laying than the other two primary host plants viz. *T. tomentosa and T. arjuna*. However, survival on *A. mylitta* larvae on *S. robusta* and *Z. jujuba* was quite low in comparison to the *T. tomentosa and T. arjuna*. Hence, based on total silk yield and fecundity *T. tomentosa and T. arjuna* are the most suitable and the efficient host plants for tasar silkworm rearing.

Rath *et al.* (1997) found significantly higher consumption, assimilation, growth and respiration of *A. mylitta* on *T. tomentosa* than *T. arjuna*. While significantly higher feeding rate was observed in *T. arjuna* during II and V instar over *T. tomentosa.*

Patil (1998) reported that *Ricinus communis* is a potential new host plant for rearing of *A. mylitta.* He found that the growth parameters and the cocoon characters of the tasar silkworm reared on castor leaves were normal. In his study, *A. mylitta* completed its life cycle in 71 to 85 days. The incubation period, larval and pupal duration ranged from 8 to 10 days, 33 to 40 days and 30 to 35 days, respectively. Further, the effective rate of rearing, weight of matured larvae, cocoon, shell, and pupae ranged from 70-85 per cent, 30-35g, 10-12 g, 1.2-1.5 g and 8-9 g, respectively. The fecundity ranged from 250 to 275 eggs.

Sinha *et al.* (2000) studied the consumption and utilisation of *Shorea robusta* leaves in Laria larvae of *A. mylitta* and found that the average total consumption of an individual larva was 108.06 gram.

Rath (2000) studied the growth, development and oviposition potential of *A. mylitta* after feeding the larvae with three host plants viz., *T. tomentosa, T. arjuna* and *Z. Jujuba* in first rearing season. They found *T. tomentosa* as best host plant for the larvae of *A. mylitta* in all respects. The larval, pupal, and adult characters along with the oviposition potential were found to be better on *T. tomentosa*.

Banagade and Tembhare (2002) studied the effect of some exogenous factors such as photoperiod, starvation, food plants, and supplementary food on silk gland protein in *A. mylitta* and concluded that starvation caused significant reduction in total protein concentration. Among the three food plants tested viz., *T. tomentosa, T. arjuna* and *Anogeissus latifolia,* the highest silk gland total protein concentration was recorded due to feeding on *T. tomentosa* leaves, suggesting the most preferable host plant for *A. mylitta*.

Rath *et al.* (2003b) carried out trial rearing of *A. mylitta* on Cashew nut *(Anacardium occidentale)* in Ranchi condition in during crop and recorded an average yield of 25 cocoons per dfl. They recorded an average fecundity of 230 eggs; average hatching of 78%; but ERR was very low 13.85%, cocoon weight was 12.85 g; shell weight was 1.40 g; filament length was 10.89 m; NBFL was 505 m; SR% was 16.4% with denier of 10; Pupation (90%); pupa weight (10.07 g); adult emergence (90%); male emergence (63.0 %); female emergence (37%); average weight of male moth (2.5 g); average weight of female moth (6.0 g); average fecundity (193 eggs) with average hatching (82.8%).

Rath *et al.* (2003a) studied food allocation budgeting in *A. mylitta* fed on *T. tomentosa* and found that the relative growth rate (RGR) reached its peak during II instar (0.523), and declined thereafter until V instar (0.088). He further reported that RGR of the developing larva was 0.396 during I instar reached its highest value during II instar (0.523), which again tend to decline to the lowest during V instar (0.088).

Rath *et al.* (2008) studied the impact of food plant on reproductive and commercial parameters in *A. mylitta* by feeding the same host plants for six generations. Larvae were fed upon *T. tomentosa*, *T. arjuna* and *Z. jujuba*. They found 85.9 % improvement in the fecundity on *T. tomentosa*, 58% on *T. arjuna* and 49.7% on Z. Jujuba. Likewise in commercial parameters, the shell weight in male showed an improvement of 52.9%, 45.8% and 42.1% on *T. tomentosa*, *T. arjuna* and *Z. Jujuba*, respectively. Their study revealed the comparative superiority of *T. tomentosa* over *T. arjuna* and *Z. jujuba*.

Reddy *et al.* (2009) studied the performance potential of Daba ecorace of *A. mylitta* on *Terminalia arjuna* under agro-climatic condition of Ranchi and recorded observations on various parameters viz., fecundity (180-280 eggs); hatching (80-90 %); cocoon yield/dfl (45-70); peduncle length (3.51-6.83 cm); cocoon length (4.85-5.21 cm); cocoon width (2.95-3.17 cm); cocoon volume (26.70-32.24 cc); cocoon weight (09.20-12.83 g); pupal weight (07.72-10.33 g); shell weight (1.25-2.36 g); silk ratio (14.13-16.28%); silk yield/1000 cocoons (812-1417 g);

silk recovery (52-71%); silk filament length (475-1240 m); non-breakable filament length (79-475 m); and denier (9-11 d).

Yadav and Mahobia (2009) reared Daba ecorace of *A. mylitta* on *T. tomentosa, T. arjuna* and *L. parviflora* and in their combinations. The productivity of cocoons from a single disease free laying remained 4.8 cocoons on *L. parviflora* being the lowest and 45.6 cocoons on *T. tomentosa* being the highest. However, there was no difference in the yield/dfl on *T. tomentosa* and *T. arjuna*. They concluded that the cocoon yield on *L. parviflora* can be increased if this food plant is used in the fifth instar of larvae, which accounts 80% of leaf consumption, after rearing either on *T. arjuna* or *T. tomentosa* up to fourth instar. They concluded that *L. parviflora* can be utilized for tasar silkworm rearing in the fifth instar where the food of prime choice; *T. tomentosa* and *T. arjuna* are in scarce and *L. parviflora* are in abundance.

Kumar *et al.* (2011) carried out a bioassay studies of *A. mylitta* in different accessions of *Terminalia arjuna* (18), *T. tomentosa* (9), *T. chebula* (1) and *Anogeissus latifolia* (1) during first rearing season of July-August 2010 and found larval weight of 40.55 g on *T. tomentosa,* followed by 40.4 g, 39.4 g, 32.8 and on *T. arjuna, A. latifolia,* and *T. chebula*, respectively. However, maximum larval period was 30 days on *T. chebula*, followed by 29 days on *A. latifolia,* 28 days on *T. tomentosa* and 27 days on *T. arjuna*, respectively.

Deka and Kumari (2013) assessed the affect of six food plant species viz., *T. tomentosa, T. arjuna*, *T. bellirica, T. chebula*, *L. speciosa* and *L. parviflora* on rearing performance and cocoon characteristics of *A. mylitta* in the agro-climatic conditions of Ranchi, Jharkhand. Performance of *L. speciosa* on the cocoon productivity and silk ratio of *A. mylitta* was found comparable to *T. tomentosa* and *T. arjuna.* Further they reported that the leaves of *T. arjuna*, *T. tomentosa* and *L. speciosa* possesses more leaf moisture, chlorophyll, protein and carbohydrate contents to support better larval growth of *A. mylitta* in comparison to its rearing on *T. bellirica*, *T. chebula* and *L. parviflora.* Their study indicated the commercial perspective of *L. speciosa* as alternate primary food plant for forest based rearing of *A. mylitta* in agro-climatic conditions of Ranchi.

Kumar *et al.* (2012) studied the effect of different forestry host plant viz., *Terminalia arjuna, T. bellirica, T. chebula, T. tomentosa, L. parviflora* and *L. speciosa* on larval duration (days), larval weight(g), Single cocoon weight (g), Single shell weight (g) and Silk ratio (%) of Daba ecorace of *A. mylitta* during first crop of July-August under agro-climatic condition of Ranchi. They found that host plants significantly affected all the studied parameters.

Reddy *et al.* (2012) analyzed the economic viability of *A. mylitta* on *Lagerstroemia parviflora* food plant in comparison with *T. tomentosa* plant in the agro-climatic conditions of Jharkhand. Their comparative study on rearing and cocoon quality among *L. parviflora* and *T. tomentosa* revealed that the effective rate of rearing (ERR), cocoon and silk yield were lower in *L. parviflora*, while the other commercially important characters like, larval, cocoon and shell weights, pupation and silk ratios have shown improvement over *T. tomentosa*. Their study indicated that the commercial prospective of *L. parviflora* might be explored in Jharkhand as alternative food plant for *A. mylitta* during exigencies.

A number of studies have been carried out on cocoon and silk characteristics of other silk producing insects reared on different host plants in different agro-climatic conditions. For example, Poonia (1978) studied utilisation of food and rate of growth of eri silkworm larvae *Philosamia ricini* on Castor, *Ricinus communis.* Reddy and Alfred (1979) studied the utilisation of Castor by *Philosamia ricini* larvae of fifth instar and found that there was direct correlation between age of larvae and body weight obtained. Thangavelu and Phukon (1983) studied the rearing performance of eri silkworm *Samia cynthia ricini* on Castor, Kesseru, tapioca, and Barkesseru. Badan and Tara (1984) recorded the comparative weight gain in silkworm *Bombyx mori* fed on five different varieties of mulberry to find out best mulberry variety of the region based on studying various indices of silkworm. Devaiah *et al.* (1985) evaluated five different host plants viz. Castor, tapioca, white plumeria and red plumeria for the rearing *Samia cynthia ricini.* Saraswat (1992) studied efficacy of *Quricus incana, Q. himalayana,* and *Q. semicarpiflora* on quantitative characters of oak tasar silkworm, *A. proylei.* They found significant gain in ERR and cocoon weight of *A. proylei* on *Q. semicarpiflora* than other two host plants. Biswas and Das (2001) studied the impact of feeding of different host plant species on the larval duration, larval growth, ERR, cocoon parameters and fecundity of eri silk moth, *Samia ricini.* Naik *et al.* (2010) carried out a study on the growth, development, and economic cocoon parameters of eri silkworm *Samia cynthia ricini* on different host plants. Rajesh Kumar and Elangovan (2010) assessed the rearing parameters of eri silkworm, *Philosamia ricini* on different host plants viz. Castor (*Ricinus communis*), Tapioca (*Manihot utilisima*), Jatropha (*Jatropha curcas*), and Papaya (*Carica papaya*). Singh (2010) assessed the effect of different host plants viz., *Shorea robusta, Ricinus communis, Murraya koenigii, Mallotus philippinensis, Syzygium cummunis,* and *Dalbergia sisso* on the biology of polyphagous insect *Ascotis imparata* in Uttarakhand. Deka *et al.* (2011) conducted study on larval growth and spinning parameters of eri silkworm, *Samia cynthia ricini* on Castor, Kesseru, and Tapioca. Faisal *et al.* (2011) studied the suitability of four host plants of forestry importance viz., *Paulownia fortunei*, *Populus deltoides*, *Tectona grandis* and *Toona ciliata* on the larval development of polyphagous defoliator, *Eupterote undata* (Lepidoptera: Eupterotidae). They found significant difference in duration of larval stages and weight gained by different larval instars of *E. Undata* reared on above food plants. Shin *et al.* (2012) studied cocoon characteristics of silkworm, *Antheraea pernyi* reared in Korean Oak. Literature is also available on food intake and utilisation in different instars of both mulberry (Horie, 1962; Periasamy *et al.,* 1984; Haniffa *et al.,* 1988; Pillai, 1989; Kurubayashi *et al.,* 1990; Teznov *et al.,* 1999;) and non-mulberry silkworms (Poonia, 1978; Pant *et al.,* 1986; Barah *et al.,* 1989; Ojha *et al.,* 2000; Rath, 2005) in indoor condition.

Besides silkworm, literatures are also available on effect of host plants on growth and development of other insects also. Smith and Nethcott, 1951) studied the effects of various food plants on the rearing of *Melanoplus mexicanus* and reported that consumption and utilisation rate differs with different food plants. Barbosa and Jane (1979) reported that the development and survival of gypsy moth (*Lymantria dispar*) larvae is strongly influenced by the host plant upon which they feed. Carne (1966) studied the growth and food consumption of *Paropsis atomaria* larvae and reported that the larvae ingested largest quantity of food during second instar. Hamilton and Lechowicz (1991) conducted outdoor rearing of gypsy moth larvae under natural temperature and photoperiod regimes on red oak (*Quercus rubra* L.) and sugar maple (*Acer saccharum* Marsh). Xue *et al.* (2009) studied the effects of different host plants on larval and pupal development and survival, and longevity and fecundity of adults of *Spodoptera litura* and found that all of the biological parameters were significantly affected by the host plants. Shahout *et al.* (2011) assessed the influence and mechanism of different host plants on the growth, development and, fecundity of reproductive system of common cutworm *Spodoptera litura.* Assadi *et al.* (2012) conducted a study on the effect of feeding on four different forest trees viz. *Quercus castanifolia, Alnus glutinosa*, *Parotia persica,* and *Acer velutinum* on the biology and feeding indices of *Lymantria dispar* L. Shields *et al.* (2012) investigated the feeding preferences of fifth-instar larvae of *Lymantria dispar* on seven over story tree species. Several workers undertook studies on polyphagous insects by offering them different host plants on larval growth, weight gain, pupal formation, adult emergence, fecundity etc. (Basu, 1944; Srivastava, 1959; Singh and Byas, 1975; Dubey *et al.,* 1981).

Reproductive potential of *A. mylitta* on different forestry host plants

The fertility of an adult insect depends in whole or in part upon the adequacy of its nutrition during the larval stages (Waldbauer, 1968). Lepidopteran larvae consume their total food requirements during larval stages to accumulate sufficient food energy to tide over the non-feeding adult to lay eggs (Rath, 2005). *A. mylitta* take neither food nor water during the adult stage, so all the nutritional requirements for bodily activity during adult life of a week or two and for the development of hundreds of eggs by the female is obtained from food stored during larval life (Trager, 1953).

Reproduction in insects is very closely related to nutritional factor of the host plant (Rath, 2000). Food deprivation during the larval period had a negative impact on the fecundity in many insects including sericigenous species (McGinnis and Kasting, 1959; Bhanot and Kapil, 1973; Muthukrishnan *et al.,* 1978; Srivastava *et al.,* 1982; Nath *et al.,* 1990; Rath *et al.,* 2004). Awmack and Leather (2002) opined that the host plant quality is a key determinant of the fecundity of herbivorous insects. Host plant qualities such as carbon, nitrogen, and defensive metabolites directly affect potential and achieved herbivore fecundity. Host plant quality also affects insect reproductive strategies viz., egg size, the allocation of resources to eggs, and the choice of oviposition sites.

According to Bhattacharya and Pant (1976), the calculation of the adult formation from pupal stage throws light on the nature of inhibitory effect or nutritional requirements for a definite stage of the insect. In general, unmated males and females live longer than mated sexes; however, under natural conditions it would be desirable if both sexes live longer even after mating. Relatively little attention has been paid in this field for evaluating a diet for *A. mylitta*.

The pupal weight of eri silkworm *Samia cynthia ricini* was found to influence the adult longevity on castor (Nagalakshmamma, 1987). The longevity of male and female moths influences the grainage performance of *B. mori* L. (Rajanna *et al.,* 1999; Krishnaprasad *et al.,* 2002) and *A. mylitta* (Rath *et al.,* 2007). The effect of various food plants on longevity and fecundity on adults of *D. oblious* has also been reported by Pandey *et al.* (1968).

There are reports that incubation period of silkworm egg vary with variation in host plant species (Jolly *et al.,* 1979; Sarkar, 1980; Reddy *et al.,* 1989; Naik *et al.,* 2010). Sengupta and Singh (1974) recorded the shortest incubation period (8 days) of eri silkworm, *Samia cynthia ricini* fed on Castor.

According to Raja Ram and Samson, (1991) hatching percentage of silkworm is affected by the kind of the host plant. Hamilton and Lechowicz (1991) found that the egg masses of gypsy moth larvae reared on oak tree hatched completely than did those from moths reared on maple tree.

Mishra *et al.* (1997) studied the reproductive behaviour of *A. mylitta* reared on *T. tomentosa, T. arjuna* and *S. robusta* plants in different seasons in Durgapur Orissa, India and reported that the type of food plants as well as seasonal variations affect the reproductive behaviour in term of percent emergence, coupling, hatchability and fecundity in *A. mylitta.*

Rath *et al.* (2003a) found that food consumption and utilisation differ significantly in male and female. Female has greater nutritional accumulation, which is associated with egg production. He reported that female A. *mylitta* larva ingest 15.7 % more food than the male.

Rath (2005) studied the effect of quantitative nutrition on adult characters and reproductive fitness in *A. mylitta*. He found that the adult weight had strong effect on the reproductive potential in the form of moth survivability, emergence percentage, fecundity, fertility, egg weight and weight of hatched out larva.

Reddy *et al.* (2010) reported that host plants significantly affect the total coupling percentage of *A. mylitta* reared on *T. tomentosa* and *L. parviflora*. Coupling percentage was found significantly higher on *T. tomentosa* (70.4 %) than *L parviflora* (60.8 %).

It is reported that different varieties of food plants influence considerably the fecundity and cocoon weight in the mulberry silk moth *B. mori* (Govindan and Magadum, 1987; Haniffa and Punitam, 1988; Opender and Tikku, 1979; Bari and Islam, 1985; Sharma and Badan 1986; Basu *et al.,*1995).

Srivastava *et al.* (1982) studied the effects of food deprivation on larval duration, weight of cocoon and fecundity of eri silkworm *Philosamia ricini.* Sankarperumal *et al.* (1989) assessed the influence of three host plants, viz. *Ricinus communis, Helianthus annuus* and *Arachis hypogea,* on the organic constituents and fecundity of *Spodoptera litura.* Bogawat (1967) studied on the biology of mustard saw fly *Athalia proxima* (Hymenoptera: Tenthredinidae) on twelve different host plants and reported that pre-oviposition period of *Athalia proxima* was not affected, but the fecundity was found variable with the host plants. Bhardwaj and Kushwaha (1976) found that the pupae formation and the adult emergence of *Amsacta Lineola* got affected when offered five different host plants. Singh (1976) described that when *Utetheisa pulchella* was fed with leaves of *crotolaria juncea* and *heliotropium indicun* resulted in variations in the adult emergence ranging from 71% to 88%.

Economic traits of cocoons and silk production efficiency of *A. mylitta* on different forest tree species

Influence of host plant and rearing season on productivity of silk substances has been reported in silkworms (Ueda *et al.,* 1971; Hough and Pimental, 1978; Pillai *et al.,* 1987; Lindroth and Hemming, 1990). Sinha and Sinha (1994) have given detailed genetic analysis of quantitative traits of *A. mylitta*. Silk producing insects present a great deal of variation in colour and morphological characters fed on different host plants (Lefroy, 1909; Crotch, 1956; Pandey, 1995). Better the food quality, greater would be the chances of getting the good cocoon harvest in *A. mylitta* (Sinha *et al.,* 1986). The cocoon shell weight and cocoon shell ratio were found highly influenced by the type of food plants and the environment of the silkworms' rearing (Siddiqui *et al.,* 2006).

According to Abraham *et al.* (2004), tropical tasar silk is superior in quality to other silks including mulberry, muga, and eri silks. Akai (1998) reported that cocoon filament of *A. mylitta* is the thickest among all the silkworm species and with a porous structure; it is most suitable for fashionable clothing and sportwear.

Srivastava *et al.* (1994) suggested that silk ratio is the second most reliable economic character after effective rate of rearing for assessing the efficacy of forestry host plants for *A. mylitta*. Devaiah and Dayashankar (1982) reported that cocoon weight, shell weight largely depends on type of hosts provided to the silkworm.

Panda (1972) collected tasar seed cocoons of *Antheraea paphia* from different regions of Odisha, separated them according to their peduncle characters, colour, and sex, and further calculated the correlation coefficient values for different characters. He also reported that live weight of female cocoons of *A. paphia* were significantly more than males, irrespective of variety and colour.

Sengupta *et al.* (2002) recorded significantly higher filament length of Daba (Bivoltine) ecorace of *A. mylitta* in second crop (959.750± 119.486 m) than first crop (517 ± 50.697 m). Srivastava (1986) found that the Sal fed cocoons of *A. mylitta* were rich in silk ratio percentage, while effective yield of cocoons was low. Efficacy of Arjun towards cocoon weight was found higher but low for effective yield and silk ratio percentage. Further, Asan has shown better performance for cocoon yield, cocoon weight, and silk ratio.

Kumar *et al.* (2006) carried out bioassay studies of *A. mylitta* on different accessions of *Terminalia* spp. and *L. speciosa* in Ranchi condition and recorded cocoon weight, shell weight, SR percentage, filament length, non breakable filament length and Denier.

Kumar *et al.* (2011) reported that *T. tomentosa* fed larvae of *A. mylitta* produces highest cocoon weight of 13.45 g in comparison to the larvae fed on *T. arjuna* (12.37 g); *A. latifolia* (12.48 g) and *T. chebula* (10.70 g). They found maximum shell weight of *A. mylitta* cocoon on *T. tomentosa* (2.06 g) followed by *T. arjuna* (1.78 g), *A. latifolia* (1.67 g) and *T. chebula* (1.19 g) during first crop rearing in Ranchi agro-climatic condition. They also recorded that *A. latifolia* fed larvae produced maximum SR percentage of 14.27% followed by *T. tomentosa* (14.02 %), *T. arjuna* (13.71%) and *T. chebula* (11.4%), respectively.

Dash *et al.* (2012) evaluated the length, breadth, and weight of pupa of *A. mylitta* reared on different forestry host plants viz., *T. alata, T. arjuna, S. robusta, Z. jujube, L. parviflora, A. latifolia, T. bellirica,* and *S. cumini* in rainy season at lower, medium, and higher altitudes in Odisha. Their study indicated that *A. mylitta* larvae reared on *S. robusta* showed significantly highest values of all the pupal growth parameters. The gradation of eight food plants in respect of the pupal growth of *A. mylitta* was found as *S. robusta* > *T. alata* > *T. arjuna* > *Z. jujube* > *L. parviflora* > *A. latifolia* > *T. bellirica* > *S. cumini*.

Rath *et al.* (1997) found significant variation in silk productivity of *A. mylitta* reared on *T. tomentosa* and *T. arjuna*. His results indicated that the larvae fed on *T. tomentosa* produced higher silk than *T arjuna*. Thus, *T. tomentosa* proves its comparative superiority over *T. arjuna.*

Raja Ram and Saradchandra (1998) reared eri silkworm on the leaves of phutkoul, castor and kesseru and observed highest cocoon weight of 2.45 g on castor followed by 2.19 g on kesseru, whereas it was found lowest (2.00 g) on phutkoul. Reddy *et al.* (1989) studied pupal weight, cocoon yield, shell ratio, and reproduction of *Samia cynthia ricini* on castor, tapioca, plumeria and ailanthus and found highest shell ratio of 12.10 on Castor. Sengupta and Barah (1991) studied female pupal weight and fecundity of mother moth of *A. assama* with four different food plants. Raja Ram and Samson (1998) assessed the effect of different forestry host plants viz., Som *(M. bombycina* king), Soalu (*L. polyantha* Juss), Dighloti (*Litsaea salicifolia* Roxb), and Majankuri *(Litsaea citrate* Blume) on rearing performance and cocoon characters muga silkworm, *A. assama.* Xue *et al.* (2009) reported that larval food directly affects size and weight of the pupae of *Spodoptera litura* and the female pupae are always heavier than male pupae.

Correlation and regression studies between different variables of *A. mylitta*

Jolly (1965) reported that the shell weight has positive and highly significant correlation with breadth of cocoon. Panda (1972) found that the live weights of cocoons of *Antheraea paphia* were positively correlated with its length and breadth. He also found that length of the cocoon has significant positive correlation with breadth of the cocoons, but he observed negative correlation with peduncle length.

Rahman and Rahman (1989) studied the correlation and path analysis of six cocoon characters of eri silkworm *Samia cynthia ricini* B. and found that cocoon shell ratio showed highly significant positive correlation with cocoon.

Siddiqui *et al.* (1989) concluded that larval weight and fecundity has the highest direct effect on silk yield. Effective rate of the rearing (ERR) was identified the other important component that contribute directly in positive direction towards silk yield through cocoon weight and shell weight.

Krishna *et al.* (1990) carried out multiple regression analysis for some quantitative traits in mulberry silkworm, *Bombyx mori*, considering cocoon weight, shell weight and shell ratio as dependent variables and other traits being independent variables. They found that with cocoon weight as dependent variable, pupal weight alone contributed for 99.20% variation, while cocoon filament weight accounted for 97.5% variation in cocoon shell weight.

Yadav *et al.* (2001) found significant positive correlation between weight of female moth and its fecundity in *Antheraea paphia.* Their study indicated that fecundity of a moth increases with increase in the body weight of female moth.

Subramanian *et al.* (2012) carried out correlation studies between cocoon weight, adult emergence, copulation potential, fecundity, eggs per gram and egg hatchability of *Samia cynthia ricini* and found that the cocoon weights; fecundity; egg hatchability have significant positive correlation. Whereas, cocoon weight and eggs per gram have significant negative correlation. Yadav and Goswami (1989) carried out correlation and regression analysis between cocoon weight and shell weight in muga silkworm on two different types of food plants. Calvo and Molina (2005) studied fecundity and body size relationship of *Streblote panda* and found strong relationship among fecundity and pupal weight and adult weight.

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