Chapter - II

REVIEW OF LITERATURE

2.1 Muga silkworm rearing in outdoor and indoor condition :

The muga silkworm, *Antheraea assama* is a semi domesticated multivoltine, polyphagous insect having about six broods in a year (Scitz, 1933). It has been reported that the growth and development of muga silkworm, its pupal weight, shell weight, fecundity as well as reelability of silk are greatly influenced by the environmental conditions during different reasons (Thangavelu and Sahu, 1986, Yadav and Goswami, 1999). Out of the six broods of Muga Silkworm, two are popular for commercial rearing (Thangavelu and Sahu, 1986; Yadav and Goswami, 1999) which are conducted during May – June and October – November. The two seasons, spring (May – June) and autumn (October – November) are preferred for commercial rearing because the climatic conditions during these period are favourable for growth and development of muga silkworm.

The commercial rearing however is carried out mostly under outdoor conditions. The outdoor rearing of the worms subjects them to environmental constraints such as rain, hailstorm and a number of natural predators (e.g. bird). Due to compulsion of outdoor rearing, dependence on favourable climatic conditions for the growth and development of the worm has become quite high, and hence only two commercial rearing are possible although the insect has six broods in a year.

Success of large scale indoor rearing is not very encouraging despite some attempts made in the past (Thangavelu and Sahu, 1983, 1986). It is obvious that before attempting indoor rearing of muga silkworm, a detailed knowledge about its feeding behaviour, physiology of feeding and digestion are essential. It is to be noted that reports on the basic studies on Muga Silk worm are extremely low (Dey *et al.*, 1997; Hazarika and Bardoloi, 1998 ; Dey, 1999) and probably this lacuna in our knowledge is one of the reasons for less success in any experimentation with the worm, including indoor rearing.

Various methods for early instar indoor rearing of tasar silk worm were reported by various authors (Alam *et al.*, 1991 and Jayaprakash *et al.*, 1993). Naveen and Savanurmath (1998) have been successfully domesticated tasar silkmoth, *Antheraea mylitta*. In order to achieve higher economy and effective rearing rate the methodology they suggested may attract farmers who like to try the production at higher magnitude.

In Simlipal biosphere reserve, Orissa, *Antheraea paphia* resides in two eco-races namely, Modal and Nalia. Domestication of this species was not successful due to its wild nature previously. However, Nayak and Jagannatha Rao (1998) by use of both natural and artificial diet at ambient temperature and humidity domesticated the species. Cocoon weight, shell weight, pupal weight and fecundity of the silkworm larva feeding on natural diet was very much akin with its parents.

Partial indoor rearing upto third instar of *Antheraea mylitta* showed a significant gain of 34.75% in ERR, uniform and healthy growth of silkworm in the late age and improvement in cocoon, pupal and shell weight of female, dry larval weight, raw silk and filament length with little improvement in denier were observed over the control in the conventional infield rearing (Sudhakar Babu and Rao, 1998).

But reports on other wild silk moth *i.e.* muga silk worm regarding indoor rearing is scanty. Thangavelu and Sahu (1983, 1986) conducted indoor rearing of muga silk worm inside the room by keeping the food plant branches in water contained in earthen pot and these were kept in a wooden stand and the whole set up was covered with polythene cover, except the ground surface and established the suitability of indoor rearing. Thangavelu and Sahu (1983) reported that som and soalu were more suitable food plant for indoor rearing than digloti. Studies indicate that higher effective rate of rearing, cocoon weight during July-August than other seasons may be due to degeneration (Choudhary *et al.*, 1998), season variation (Thangavelu and Sahu, 1983), high humidity (82.05%), and favourable temperature (24.5^{0}C) is suitable for indoor rearing. Moreover, improvement over outdoor rearing in effective rate of rearing and cocoon weight has been reported by Thangavelu and Sahu (1986) from a year round experiment.

According to Raja Ram and Sinha (2004), from the comparative study of indoor and outdoor rearing revealed that the variation was non-significant; however larval period 32 days, effective rate of rearing 24.25%, single cocoon weight 5.3 gm single shell weight 0.49gm and silk ratio 9.24% was higher in outdoor than indoor rearing. According to the result, the indoor rearing was found to be encouraging on economic characters. The establishment of indoor rearing on suitable genotype of primary food plant would increase the economic character of the muga silk worm. Azad *et al,* (2000) also conducted indoor rearing of muga silk worm and observed better results. Annual report (1995-96) of CMRS, CSB (Boko, Assam) (Anonymous, 1996) reflected that during favourable seasons, indoor rearing till the third instar is not effective. However, during unfavorable seasons the technique did show some edge over the control. According to Hazarika *et al*, (2006) larval period of the indoor reared domesticated strain of *Antheraea assama* on detached leaves of *Machilus bombycina* was found longer than that of the outdoor one, while, the latter yielded heavier cocoons (5.95 ± 0.29g). However, the silk ratio was found higher in the indoor reared group (7.54 ± 0.39 g) without showing much difference in pupal weight and effective rate of rearing. Hazarika and Deka (2002) opined that silk ratio of indoor rearing (7.54 ± 0.39%) was significantly higher than that of outdoor rearing (6.81 ± 0.19%). The ERR was almost similar in both the cases. However, the larval period in the indoor condition was prolonged by more than 10 days.

In West Bengal condition, Ray (2003) working on muga silk worm indoor rearing as complete indoor, partial indoor (upto 4^{th}, upto 3^{rd}, upto 2^{nd} and upto 1^{st}) and complete outdoor found that the survivability was highest in complete indoor rearing and lowest in complete outdoor rearing which was almost one fourth of complete indoor and half or partial indoor upto 3^{rd} instar. Moreover, cocoon characters were also better from partial indoor rearing upto 3^{rd} instar.

2.2. Nutritional efficiencies of muga silkworm :

Nutritional efficiency is considered important to assess the cost benefit ratio of sericulture practice upto the level of cocoon production (Rahmathulla *et al.*, 2002). The feed consumption has a direct impact on larval weight, cocoon weight, amount of silk produced and number of eggs laid (Magadum *et al.*, 1996a). At the same time, success of silkworm breed in any eco-climatic condition depends on its acclimatization ability, survival efficiency to produce more dry matter (silk / egg) per unit food intake at the shortest duration without hampering quality parameters (Anantha Raman *et al.*, 1993).

Horie *et al.* (1976) and Jaksheva and Genova (1991) have reported higher ingesta values for fourth and fifth instars of different breeds of mulberry silkworm. Variation in ingesta values among breeds of *B. mori* have also been reported (Yamamoto and Fugimaki, 1982). Low feeding rate, nutritional inadequacy of feed or combination of both lead to poor growth (Waldbauer, 1964). The poor ingestion recorded by Anantha Raman *et al.* (1993) in mulberry hybrids is due to low growth potential. Benchamin and Jolly (1984) have reported 88.67% higher ingesta in NB_{18} over the indigenous breed, PM. More than 85% food consumption in the last instar of *B. mori* has been reported by (Hiratsuka, 1920; Benchamin and Jolly, 1984; Naik and Delvi, 1987; Anantha Raman *et al.*, 1993, 1995, Rahamathulla *et al.*, 2006). This is also true for non-mulberry silkworm especially in *Antheraea mylitta* (Sinha *et al.*, 1998, 2001).

Excreta values progressively increases as growth advances. The production of excreta depends on quality of food, rate of food intake, absorption rate and also the retention time of food in the gut. Higher food intake tends to mobilize the gut contents faster and provides less time for enzyme activity and food absorption making the efficiency poor (Waldbauer, 1964).

Reference ratio (RR) is an indirect expression of absorption and assimilation of food. It also expresses the ingesta requirement per unit excreta production. Higher RR values mean high rate of digestion and absorption of food. This is noticed in young instars. The poor RR recorded in fourth and fifth instar is due to poor absorption and digestion and this is true for both mulberry and non-mulberry silkworm. Excreta production and RR values depends on the quality of food, retention time, rate of enzyme activity and the ingestion rate. Higher RR values in young instars is due to the feeding habits of larva on the succulent and nutritionally rich leaf lamina without engulfing the venation zones (Anantha Raman *et al.*, 1993). Mathavan and Pandian (1974) recorded 1.5 RR value for the fifth instar larvae of lepidopterans.

Consumption index explains in a nutshell the rate at which nutrients enter into digestive system and is expressed in fresh or dry weight of food per mean larval body weight per day

(Prabhakar *et al.*, 2000). Soo Hoo and Fraenkel (1966) reported that nutritionally inadequate diet may be ingested at a faster rate. Prabhakar *et al.* (2000) further opined that growth rate explains how much of dry matter increased in the larvae per gram of body weight per day. It directly influences the rate of development, which depends on quality of host or physiological stage of the larvae. Pant (1986) reported that consumption index (CI) and growth rate (GR) were declined during 5^{th} instar larval life and CI and GR appeared inversely proportional to the gross efficiency.

Three mulberry silkworm race namely pure Mysore, NB_{18} and PM x NB_{10} reared on three varieties of mulberry viz. Mysore local, M_5 and S_{54} grown under rainfed condition was studied by Prabhakar *et al.*, 2000. NB_{18} fed on M_5 recorded lower consumption index and higher growth rate. Furthermore, CI was negatively correlated with the characters like fecundity, larval duration, silk gland weight and length, cocoon weight, shell weight, cocoon shell ratio, cocoon filament length and denier, but positively related with floss content and number of breaks per cocoon while reverse trend was established with GR. Nutritional and feed conversion efficiency parameters of CSR16 x CSR17 were studied by Rahamathulla *et al.* (2006). Nutritional indices like ingesta, digesta, approximate digestability, reference ratio and consumption index were recorded significantly less in CSR16 x CSR17 when compared with control (CSR2 x CSR4).

The approximate digestibility is higher in early instars which gradually reduces, lowest being in fifth instar in both mulberry (Horie *et al.*, 1976; Ito and Kobayashi, 1978; Horie and Watanabe, 1983; Benchamin and Jolly, 1984) and tasar silkworm (Sinha *et al.*, 1998 and 2001). The reduced AD in fifth instar is due to high content of dry matter in the feed. Efficiency of conversion of ingested food is an overall measure of larval ability to utilize the ingested food for growth. ECD is the proportion of digested food utilized for the body built up. ECD is not directly dependent upon the digestibility but it varies with the level of nutrient intake, and with the nutritional value of the food. The ECI values are higher in early instars due to quality of food and small size of larva. The low ECI in late instars is because of aging, duration of instar, high fibrous content and also low absorption and high utilization of energy for organ development. (Matsumara *et al.*, 1955; Horie *et al.*, 1976; Benchamin and Jolly., 1984; Anantha Raman *et al.*, 1993). However, ECI and ECD values increased from first to fourth instar and then declined in the fifth instar in tasar silkworm as reported by Sinha *et al.* (1998). A number of workers supported this trend of rise and fall in ECI and ECD in different insects (Mukherjee and Guppy, 1970; Latheef and Harcourt, 1972 and Bailey, 1976). The mean ingesta and digesta increases as larval growth progresses. The values are low in younger instar and higher in late instar. This tendency is due to lower gut volume, low ingesta and small size of body. Moreover, lesser ingesta and digesta requirement to produce unit larval dry weight is due to higher efficiency in assimilation by the silkworm (Matsumara *et al.*, 1955; Horie *et al.*, 1976; Benchamin and Jolly, 1984; Anantha Raman *et al.*, 1993). Better efficiency of converting the digesta and ingesta into cocoon and cocoon shell as well as less ingesta and digesta requirement to produce unit cocoon and shell production reflect better survival efficiency of any breed in any eco climatic condition. (Anantha Raman *et al.*, 1993).

However, the efficiency of converting ingested and digested food into the body, cocoon and cocoon shell varies among silkworm races under the influence of season and host plant varieties (Anantha Raman *et al.*, 1995). Nutritional quality as well as environmental conditions have greater impact on regulation over the quantum of ingesta, digesta and digestibility of food among silkworm (Ito, 1972).

2.2.1. Nutritional efficiency as influenced by host plant :

The qualitative aspect of nutrition in any insect is the fundamental importance for understanding the insect plant relationship (Waldbauer, 1968; Bhattacharya and Pant, 1976). At the same time, various physiological activities of an organism are expressed in growth which results from the balance between matter assimilation and dissimilation by complicated phenomenon. Food ingestion, consumption and utilization patterns with relation to host plant and sex-specific differences observed in different insects have been studied quite extensively by many workers (Bailey, 1976; Biren *et al.*, 1987; Yamamoto and Fuzimata, 1960; Joshi, 1984; Slansky and Scriber, 1985). Studies on nutritional ecology of an insect become important for its commercial exploitation (Scriber and Slansky, 1981) as there exists a direct correlation between the nutritional status of the leaves and the cocoon quality in case of silkworm food plants (Srivastava *et al.*, 1998). In the insects, assimilation in the total quantity of food available to be incorporated as body substances or to be metabolized for energy (Reddy and Alfred, 1979). Studies on the consumption and utilization of food in insects facilitate the understanding of the adaptability of insects to the environment. Scriber and Slansky (1981) and Muthukrishnan and Pandian (1987) have extensively reviewed the different aspects of insect bio-energetics. Consumption and utilization of food (Yamamoto and Fujimaki, 1982) and adaptability to environmental factors vary not only among species but also among races (Periaswamy *et al.*, 1984). Also, enormous literature exists of food intake and utilization in different instars of both mulberry (Takeuchi and Kosaka, 1961 ; Kurubayashi *et al.*, 1990) and non-mulberry silkworms (Poonia, 1978, 1985; Reddy, 1983; Pant *et al.*, 1986; Barah *et al.*, 1988 and Khalequzaaman, 1990).

The credit of quantitative study on the consumption and utilization of mulberry leaves by the silkworm goes to Hiratsuka (1920). Most of studies on food utilization and nutrition of Bombyx mori were summarized as early as 1970 (Legay, 1958; Yokoyama, 1963; Ito, 1978). Horie and Watanabe (1983) have studied the utilization of food towards body growth on a daily basis. The quantity and quality of mulberry leaves consumed, digested and the digestion ratio are intimately associated with the larval weight / growth (Ito and Arai, 1963; Somioka *et al.*, 1982). If the growth rate is kept below the ideal level, the fitness may be reduced because of the extended period of vulnerability to predators and parasitoids (Price *et al.*, 1980). Sharma *et al.* (1986) and Dar *et al.* (1988) investigated various nutritional parameters in silkworms fed on different varieties of mulberry leaves. Moreover, food assimilation efficiency in *Bombyx mori* differs with the race as well as with the variety of mulberry (Hassanein *et al*, 1972). There are few reports concerning the effect of rearing conditions (Matsumara *et al.*, 1958), leaf ratio (Sunioka *et al.*, 1982 and Radhakrishnan and Delvi, 1987) and insecticides (Delvi and Naik, 1984; Pant and Katiyar, 1983 and Radhakrishnan and Delvi, 1992) on the silkworm nutrition and development.

There appears to be in a good food plant an inverse correlation between food consumption and efficiency of utilization (Soo Hoo and Fraenkel, 1966). Narayana Prakash *et al.* (1985) reported a consumption of 3.873g and 3.153g by a larva of NB_{18} x NB_7 and local x KA respectively. Horie and Watanabe (1983) observed 6.2g of ingestion per larva during fifth instar.

The average daily consumption of energy was 0.18 and 0.17 Kcal/g fresh body weight for the male and female larvae respectively. Kurubayashi (1990) reported that the total amounts of dry matter ingestion and digestion by 5th instars larvae were about 5.8g and 2.1g respectively. The highest assimilation was recorded in the 5th instar and was found to be related with the amount of food consumed (Sinha *et al.*, 1998). This is in agreement with the findings of Vats and Kaushal (1982). The consumption was maximum during the 5th instars being 80.13% of the total consumption. Magadum *et al.* (1996b) from the studies of 5th instar larvae of nine bivoltine breeds of *Bombyx mori* through regression analysis indicated that the total amount of ingesta was related to the total amount of digesta, mature larval weight, larval duration, cocoon weight, shell weight and fecundity. Yamamoto and Gamo (1976) observed a high positive correlation between ingesta and cocoon weight, shell weight and larval weight. Nutritional background of the larval stage significantly influences the status of the resulting pupae, adult and production of silk in the economically important insect like *Bombyx mori* (Fukuda *et al.*, 1963; Takano and Arai, 1978 and Aftab Ahamed *et al.*, 1998). Horie and Watanabe (1983) carried out studies on the digestion and daily utilization of mulberry leaves in *B. mori* larvae. The polyvoltine breeds varied in their growth, development, economic characters, food consumption, utilization and conversion efficiencies (Remadevi *et al.*, 1992).

The percentage digestibility and the efficiency of conversion of ingested (ECI) and digeted food (ECD) to body matter, cocoon, cocoon shell and egg are important in phytophagous insect. Other factors which appear to affect the overall nutritional efficiency with relation to particular plant are water content, protein content and possibly the fibre content.

The approximate digestibility (AD) is higher in early instars which gradually decreases and reaches the lowest in fifth instar larvae (Sinha *et al.*, 1998). The efficiency of conversion of ingested (ECI) and digested (ECD) food to body substances increased from first to fourth instars and declined in the fifth stage. A number of workers supported this trend of rise and fall in ECI and ECD in different insects (Mukherjee and Guppy, 1970; Latheef and Harcourt, 1972 and Bailey, 1976). The lower values of ECI and ECD are perhaps due to the fact that a smaller portion of ingested and digested food is used for tissue growth and major portion for its maintenance (Sinha *et al.*, 1998). In the later stages, metabolic rate is higher than the early stage and hence major portion of ingested or digested food is available for conversion to body tissues. Horie and Watanabe (1983) carried out studies on the digestion and daily utilization of mulberry leaves in *B. mori* larvae. The polyvoltine breeds varied in their growth, development, economic characters, food consumption, utilization and conversion efficiencies (Remadevi *et al.*, 1992). Hiratsuka (1920) reported 23% of ECI during its larval stage of NB_{18}. Shyamala *et al.* (1960) observed 48% ECD in larvae of *B. mori*. Yamamoto and Fuzimaki (1982) have reported that the food utilization efficiency varies markedly among the silkworm strains. The efficiency of food conversion of a silkworm hybrid, PM x NB_4 D_2 showed that AD and ECI reduced in successive instars. The ECI and ECD values for larvae were 24.20 and 56.92% (Anantha Raman *et al.*, 1993). Yokoyama (1962) recorded AD in *B. mori* during its larval stage around 41%. Periaswamy and Radhakrishnan (1985) recorded an ECD of 46 to 49% when NB_{18} larvae fed on $S_{54,}$ 36 to 42% on M_5 and 30-32% on local varieties of mulberry respectively. Yamamoto and Fujimaki (1982) reported a lower correlation of ingesta and AD for Japanese breeds and a high negative correlation was observed between cocoon shell weight and ingested dry matter for the production of unit cocoon shell weight. Remadevi *et al.* (1992) reported that low AD in *B. mori* is associated with high ECI /ECD and vice-versa. Anantha Raman *et al.* (1992) reported that the amount of dry matter ingested and digested in different instars were significantly different. The AD and ECI reduced gradually from first to fifth instars. The ECD values fluctuated from 54.47 to 59.07% in different instar.

In Cooch Behar district of West Bengal an investigation was carried out by Ray *et al.* (2000) to study the interaction of mulberry varieties (S_1, TR_{10} and Kosen) and bivoltine silkworm breeds (P_5, KPGB, P_5 x KPGB and KPGB x P_5). Among the silkworm breeds, hybrids showed better nutritional efficiencies. Kosen Variety has consistently proved its superiority to TR_{10} and S_1 as evident from shorter larval duration, low quantity of food ingestion and food balance and higher gain in weight. Furthermore, the lower consumption index and approximate digestibility are substantiated by higher conversion efficiencies by the larvae specially the hybrids fed with Kosen.

From the standpoint of conversion efficiencies to body matter, cocoon and shell it was observed by Rahamatulla *et al*, (2006) that ingesta and digesta required to produce one gram of larvae, cocoon and shell were significantly higher in control (CSR2 x CSR4) than newly evolved race (CSR16 x CSR17). Horie (1978) opined that *B. mori* larvae requires 4.5g of dry matter ingestion for a gain of one gram body weight on dry weight basis. According to Trivedy and Nair (1999), almost all nutritional efficiency indices were categorical pointers to prove that the new hybrid, BL_{44} x NB_4D_2 which established its clear edge over PM x NB_4D_2. Anantha Raman *et al.* (1993) reported that the ECI and ECD values for larvae, cocoon and cocoon-shell were 24.20, 20.18, 10.39 and 56.92, 53.38 and 27.489% and the ingesta and digesta required to produce one gram larval, cocoon and cocoon shell weight were 4.22, 4.97, 9.66 and 1.80, 1.88 and 3.65 gm respectively. It is evident from this results that among the tropical silkworms, PM x NB_4D_2 is very efficient in utilizing dry matter for body growth, cocoon and cocoon shell production.

Considerable literature are available in the field of eri silkworm, *Philosamia cynthia ricini* (Joshi and Misra, 1979; Devaiah *et al.*, 1988; Hussain and Shahjahan, 1997; Joshi, 1984, 1985; Pant *et al.*, 1986 and Reddy and Alfred, 1979) and eri silkworm is also domesticated.

The literature for tasar silkworm and muga silk worm, both are wild and being reared in field is scanty for nutritional efficiencies.

Tasar Silk worm, *Antheraea mylitta*, polyphagous insect feeds on a number of host plants of which *Terminalia arjuna, Terminalia tomentosa* and *Shorea robusta* are considered as primary food plants for commercial rearing. A feeding trial of *A. mylitta* was conducted on the foliage of *T. arjuna, T. tomentosa* and *S. robusta* to determine its food consumption, utilization and tissue growth during different larval instars. Average total consumption of an individual larvae was highest in *T. arjuna* (123.630g) followed by *T. tomentosa* (105.717g) and lowest in *S.robusta* (94.256g). Quantitalively difference in consumption, assimilation and respiration starts from second instar onwards depending on the types of food plant. From second instar onwards consumption, assimilation and respiration were found to be lowest in the worms fed on *S. robusta*. Similarly, tissue growth and efficiency of conversion of ingested and digested food to body substances recorded to be lowest from third instar onwards in the worm fed on *S.robusta*, *T. arjuna* and *T. tomentosa* behave equally in respect of efficiency of ingested and digested food to body substances. Efficiency of conversion of ingested and digested food to body substances showed increasing trend from first to fourth instars and then decreased in fifth instar in all the three cases. However, the worms fed on *T. arjuna* were found significantly superior in respect of food consumption, assimilation, respiration, tissue growth and digestibility among all the three types of food plants followed by *T. tomentosa* and *S. robusta* (Sinha *et al.*, 1998).

In *Antheraea proylei* assimilation efficiency was observed 71% (Rana *et al.*, 1987). Sinha *et al.* (1998) reported that mean values of ECI over the entire larval period were calculated to be 21.845%, 21.504% and 20.216% in *T. arjuna, T. tomentosa* and *S. robusta* respectively. The grand mean values of ECD was found 32.388%, 32.154% and 31.083% in *A. mylitta* on *T. arjuna, T. tomentosa* and *S. robusta* respectively while ECD for *A. proylei* fed on *Quercus serrata* was 34% (Rana *et al.*, 1987).

Food consumption, utilization and tissue growth during different larval instars were worked out through a feeding trial on laria eco-race of tropical tasar silkworm, *Antheraea mylitta* Drury on the foliage of *Shorea robusta*. During its larval span of 42 days, the average total consumption of an individual larva was 108.06g of which 61.81g was assimilated by the larva. The assimilation and tissue growth were found positively correlated with the leaf consumption and maturity of the larva. The approximate digestability declined with the advancement of age whereas efficiency of conversion of ingested and digested food rose up in 4th instar and decreased in the fifth instar (Sinha *et al.*, 2000).

Again, food consumption and utilization during different larval instars were quantitatively studied through a feeding trial on laria eco-race of tasar silk worm *Antheraea mylitta* Drury on the foliage of *Terminalia tomentosa*. During its larval span of 42 days, the average total consumption on an individual larva was 136.713g of which 80.518g was assimilated by the insect. The quantity of food consumption increased with the increase in age of larvae and reached its peak in the fifth instar (80.13% of total consumption). The assimilation and tissue growth were found positively correlated with the consumption and maturity of the larva. With the advancement of age, the approximate digestibility declined where as efficiency of conversion of ingested and digested food rose upto 4th instars and thereafter decreased in the fifth instar.

In Muga silkworm, the investigation in the field of nutritional efficiency is very little. Barah *et al.* (1989) tried to investigate the nutritional efficiency of *Antheraea assama* on Som plant (*Persea bombycina*). During 32 days of larval life, the total consumption was 33.925g/insect of which 21.295g were assimilated. About 80.1% of the total consumption took place in fifth instar. Assimilation and tissue growth were positively correlated with consumption and larval age. The approximate digestibility was negatively correlated to the amount of food consumed. Efficiency of conversion of ingested and digested food increased in the first four instars and declined in the fifth instar.

The diet efficiency study involving the biochemical analysis of ingesta, larva, silk gland and excreta during various stages of development of larva provided an evidence of stage specific utilization of the dietary constituents during the larval development and spinning period. The highest value of coefficient of digestibility (CAD %) was observed for total soluble sugar (69.5%) followed by minerals (40.05%) and crude fat (29.13%) by Das *et al.* (2004). Bhattacharyya and Ray (2006) estimated the consumption of food, digestion, utilization and efficiency of conversion of food into larval body, cocoon and cocoon shell of muga silkworm utilizing leaves of som plant as food under indoor condition. Results recorded on dry weight basis and the amount of dry matter ingested and digested in different instars were significantly different. 83.62% leaves consumed in fifth instar larval stage. Highest ECI and ECD being 19.76% and 45.10% were recorded in the third instar while highest digestibility was found in first instars (53.48%). The ECI and ECD value for larva, cocoon and cocoon shell were 11.50, 10.03, 1.88 and 33.50, 29.21, 5.46% respectively. The ingesta and digesta required to produce one gram cocoon and cocoon shell weights were 9.97, 53.32 and 3.42, 18.30gm respectively.

Nutritional value of food plants either alone or in combination play significant role in larval growth and silk productivity.

In mulberry sericulture, different combinations of mulberry varieties for two growth stage (early and late) oriented bi-voltine silkworm rearing through systematic evaluation of nutritional efficiencies has been done by Ray and Deb, (2007) and they suggested Kosen – S_1 combination

(Kosen at early stage and S_1 at late stage) for higher productivity and profitability in sericulture for terai region of West Bengal.

Scanty of reports are in non-mulberry sericulture also (Raja Ram and Samson, 1998, Barah *et al.*, 1988). Biswas *et al.* (2008) studied on effect of different food plants and reared muga worms on secondary food plant after initial rearing on som and soalu and Joshi and Mishra (1979); Devaiah *et al.* (1988) and Hussain and Shahjahan (1997) on eri silkworm.

2.2.2 Nutritional efficiency as influenced by season :

There is seasonal effect of nutritional efficiencies from mulberry leaves by *B. m ori* larvae. Petkov and Mircheva (1979) emphasized that the quantity taken in and utilization of energy from the ingested food depends on age of silkworm, the norm of feeding and the season in which the silk worm reared. Silkworm takes in greatest quantity of energy from mulberry leaves in the spring season. In spring, the coefficient of digestibility was higher in comparison to those in summer and fall season. Rahmattulla *et al.* (200 2), studied nutritional indices and nutritional efficiency parameters of fifth instar larvae of newly evolved bivoltine races under different environmental conditions. In adverse environmental conditions during fifth instars, most of the nutritional efficiency parameters were recorded higher than control. During high temperature and low humidity condition comparatively high consumption, digestion and utilization of food was observed in new race. This is an indication of more efficiency of the race to feed and convert into body matter during unfavorable conditions.

The efficiency of converting the ingested and digested food into the body, cocoon and cocoon shell varies among silkworm races under the influence of season and mulberry varieties (Anantha Raman *et al.*, 1995). Nutritional quality as well as environmental conditions have greater impact on regulation over the quantum of ingesta, digesta and digestibility of food among silkworm (Ito, 1972).

Low temperature (26^0C) throughout the rearing favours higher silk conversion (Muniraju *et al.*, 1999). Dutta *et al.* (1996) opined that better growth rate and efficiency of ingested and digested food into body biomass of multivoltine *B. mori* in spring season even though the rate of food intake was lower in this season. M ultivoltine race pure Mysore showed poor ingesta, digestibility, AD, ECI and ECD values in summer. The C I and GR were high in summer (Gokulamma and Reddy, 2005).

Efficiency of conversion of mulberry leaf into silk is one of the important properties of silkworm *Bombyx mori* L. as this is of commercial value. Conversion efficiency will be influenced by factors ,temperature plays an important role in conversion of leaf into silk. The silkworm, Pure Mysore (PM) a multivoltine and NB_4D_2 a bivoltine (BV) were reared under constant temperature of 26^0, 28^0, 30^0 and 32^0C during young age and different combinations during late age to understand the relevance of temperature on leaf silk conversion and survival. Low temperature (26^0C) throughout the rearing favoured higher silk conversion (0.062mg per mg leaf intake) with better survival (87%)in bivoltine and 32^0C during young age and 26^0C during late age for multivoltine (94.4%survival). Negative correlation for survival and cocoon yield was observed with increasing temperature upto 32^0C and lethal beyond this temperature in case of bivoltine (Muniraju *et al.*, 1999).

The body temperature of silkworm varies with ambient temperature. The physiological activities, food intake and economic parameters are influenced by body temperature of silkworms (Anonymous,1972). The effect of temperature during rearing on survival, growth, cocoon production and silk quality have been studied by many workers (Matsumura and Ishizuka 1929; Kogure, 1933; Matsumara *et al.*, 1958; Ueda 1963; Udea and Harizuka, 1962; Yamamoto and Fujimaki, 1982; Verma and Atwal, 1967; Sigematsu and Takeshita 1967; Rapusas and Gabrial, 1976; Muniraju, 1995) and Muniraju *et al.* (1999) recorded low silk production when reared at high temperature and suggested 24-26^0 C as optimum for good rearing results.

It is evident from the present study that when the temperature is to go beyond 30^0C, during late age, the worms during young age are to be reared at lower temperature of 26^0C for better adaptability and productivity (Muniraju *et al.*, 1999).

The nutritional efficiency of multivoltine mulberry breeds namely, Assamese Sarupat and Nistari reared on Jatinuni and K_2 under the eco-climatic conditions of Assam in different seasons revealed better growth rate and efficiency of conversion of ingested and digested food into body biomass of the breeds in spring season even though the rate of food intake was lower in this season. The breeds were at par and season had no effect so far as food digestibility was concerned. The breeed nistari was the better converter of ingested as well as digested food to body biomass though its food intake was less and growth rate was slightly less compared to Sarupat. Jatinuni was rated as the suitable host plant in respect of food consumption, growth rate and digestibility where as K_2 exhibited better performance in respect to ECI and ECD (Dutta *et al.*, 1996).

Breed and seasonal differences in food consumption and utilization efficiencies in fifth instar of nine bivoltine breeds (36PC, JSV_6, KA, NB_1, NB_{18}, NB_4D_2, NB_7, NN_6D and SH_6) have been studied. The relative consumption was highest in 36PC (1.307) and lowest in NB_1 (1.103). The approximate digestibility varied from 30.34% (KA) to 41.79% (36PC). AD values were high in rainy season except 36PC and NN_6D, which showed high AD in summer. The reference ratio varied from 1.45 (KA) to 1.77 (36PC). The efficiencies of conversion of food ingested (17.82) and food digested (46.26) were very low in 36PC.The ingestion to body ratio and ingestion to shell ratio also varied amongst the breeds (Magadum *et al.*, 1996a).

Studies on consumption and utilization of food in two races (C-nichi and KA) of the silkworm *Bombyx mori* were conducted at three different temperature i.e., 33 ± 1^0C, 25 ± 1^0C and 17 ± 1^0C. The rearing was conducted with the help of an environment chamber fabricated for this purpose .The fourth and fifth instar consume the maximum food (90-95%) of total consumption during larval life .Hence the food consumption studies were confined to this instars. The results showed that the nutritional parameters are higher at 33^0C and lower at 17^0C in both fourth and fifth instars of the multivoltine (C-nichi) race. The bivoltine (KA) race showed higher nutritional indices at 25^0C and lower at 17^0C with a few variations between the instars. The results also revealed that the temperature not only influenced the metabolic activities of the larvae depending on age, but also on different races used in present investigation (Basavaraju *et al.*, 1998).

The multivoltine race pure Mysore and bivoltine races NB_4D_2 and CSR_5 were reared on three different mulberry varieties viz. M-5, S36 and V-1 under different environmental conditions. The combined effect of leaf quality and rearing temperature and on the nutritional parameters such as approximate digestibility (AD), efficiency of conversion of ingested (ECI) and digested food (ECD) into body matter, Reference ratio (RR), consumption index (CI) and growth rate (GR) were studied. The dry matter ingested and digested were significantly high in silkworm breeds fed with V-1 mulberry variety during winter and three silkworm races showed better efficiency of conversion of ingested and digested food into body substances with V-1. Seasons also had significant effect on ECI and ECD irrespective of the type of leaf offered. V-1 was found to be the suitable host plant for bivoltine silkworm breeds in all the three seasons of the year. However, the multivoltine pure Mysore race reared on V-1 showed poor ingesta, digestibility, AD, ECI and ECD values in summer. The CI and GR were high in summer in both pure Mysore and bivoltine breeds studied (Gokulamma and Reddy, 2005).