REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1. CONSUMPTION AND UTILIZATION OF MULBERRY LEAVES, LARVAL GROWTH AND DURATION

The consumption and utilization efficiencies of food are essential traits of insects that qualify for their growth, development and reproduction. The amount, rate and quality of food consumed particularly by lepidopteran larvae like those of *B. mori* having non-feeding, short-lived and only reproductive adult stage, influence larval growth rate, weight, developmental time and concomitant reproductive performance (Slansky and Scriber, 1985). In general, folivore caterpillars have a higher efficiency of conversion of leaf dry matter to growth as because the foods are highly nutritious and the larvae require a fast growth with accompanying food reserve(Soo Hoo and Fraenkel, 1966). As for example, the ECD of *B. mori* on mulberry leaves is 63% (Hiratsuka, 1920).

Phytophagous insects have very poor ability for water conservation. Hence, they suffer from deleterious effects if dietary water is not adequate (Waldbauer, 1962, 1964, 1968). Dietary moisture level in such insects, particularly in the caterpillars, is an important factor in the nutritional efficiency (Scriber, 1977; Reese and Beck, 1978). This acts as a primary limiting factor for the folivores (Schroeder, 1986). Low foliar water has been considered nutritionally poor (Soo Hoo and Fraenkel, 1966; Mattson and Scriber, 1987), hence reduces the growth rate of caterpillars (Scriber, 1977; Reese and Beck, 1978; Slansky and Scriber, 1985; Martin and Van't Hof, 1988; Timmins et al., 1988; Van't Hof and Martin, 1989). A low - water imposed impaired growth has also been implicated by Scriber (1979) in 16 species of forb-, shrub- and tree - feeding caterpillars.

Consumption and utilization of mulberry leaves by the bivoltine races of B. mori have been studied by several workers in Japan (Matsumura and Takeuchi, 1950; Matsumura et al., 1955; Takeuchi et al. , 1964; Ueda, 1965; Ueda and Suzuki, 1967; Horie and Watanabe, 1983 a). In Bulgaria a sex- limited differential nutritional efficiency has been observed by Tzenov(1993) and Tzenov and Petkov(1993). The percentage of water in mulberry leaves varies according to the age(Kawase, 1914; Hiratsuka, 1917) and season (Pathak and Vyas, 1988). Parpiev(1968) emphasized that high moisture content of mulberry leaves favours the palatability and also assimilability of leaf nutrients by silkworm. The over all performance of insects must depend on weight gain from larval feeding(Kestner and Smith, 1984) which is again directly related to the amount of food consumed and efficiency of utilization therefrom (Slansky, 1980). The final weight of silkworm larvae is intimately associated with the quantity and quality of food consumed (Sunioka et al., 1982). This is evident from the results of many experiments involving restriction of feeding duration (Muthukrishnan et al., 1978; Mathavan et al., 1987), food rationing (Radhakrishna and Delvi, 1987; Pillai, 1989) and number of feeds per day (Haniffa et al., 1988).

While maximum emphasis has been laid on the negative aspects of nutritional efficiency associated with low - water diets, literature on the optimum water requirement for best efficiency, or the impact of dietary water in excess of optimum requirement is scanty. The observations obtained by using diets diluted with excessive water (Timmins et al., 1988; Slansky and Wheeler, 1989) do not implicate strictly the impact of excess water on nutiritional efficiency of the caterpillars. However, Narayanaprakash et al. (1985) attempted to study the effect of food utilization efficiency in a bivoltine hybrid and a multi x bi cross breed of *B. mori.* The authors worked under tropical situation using mulberry leaves with natural high water and those made artificially to contain low levels of water. A breed specific thriving ability and utilization efficiency of food by the larvae on variable water levels were reported.

The present attempt is to measure the consumption and utilization of food, larval growth and duration of the Niatari race of *B. mori* reared on mulberry leaves containing different levels of water.

2.2. EFFICIENCIES OF CONVERSION OF CONSUMED LEAVES INTO COCOON AND SHELL

Dietary water level is important to the efficiencies of conversion of nutrients into biomass of phytophagous insects (Soo Hoo and Fraenkel, 1966; Feeny, 1975; Slansky and Scriber, 1985; Mattson and Scriber, 1987). Depending on the age older mulberry leaves contain progressively poor percentage of water and protein (Nakajima, 1931). Scriber and Slansky (1981) also agree that leaf water and nitrogen content of leaves of plants generally decline with age.

Several reports are known on the consumption and utlization efficiency of mulberry leaves into cocoon and shell(Kawase, 1914; Hiratsuka, 1917; Matsumura et. al., 1955; Ueda, 1965; Ueda and Suzuki, 1967; Horie et al., 1976; Horie and Watanabe, 1983a) Both the weight of the cocoon and shell tend to decrease when the larvae are fed with leaves in descending order from the apex of the plants. One of the causes for such decline lies with the fact that water and nitrogen contents are inversely proportional to the ages of mulberry leaves (Kawase, 1914; Hiratsuka, 1917; Nakajima, 1931; Hassanein and El Shaarawy, 1962a). Further, the varietal differences of mulberry leaves due to differential amount of water and other nutrients result in the differential efficiency of cocoon and shell production

(Machii and Katagiri, 1990). Apart from other factors, water in the leaves has been considered to limit the nitrogen utlization efficiency and thereby resulting in the differential growth and final biomass production(Feeny, 1970; Scriber, 1977; Slansky and Scriber, 1985).

In the bivoltine races of B. mori. generally the ECI and ECD values for female pupa and male cocoon -shell are higher than those for male pupa and female cocoon-shell(Horie and Watanabe, 1983a). Correspondingly the efficiency of storage of absorbed energy to pupa and cocoon-shell show sex-limited differences(Horie and Watanabe, 1985).

Narayanaprakash et al. (1985) have recorded an increased shell weight and fibroin content of the cocoons with increasing diet moisture of mulbery leaves in case of both bivoltine and multi x bi cross breeds of B. mori under tropical situation.

However, no information is available for the multivoltine ' Nistari ' race of B. mori regarding the conversion efficiency of leaf into cocoon and shell under differential moisture content of mulberry leaves particularly during the wet part of summer.

2.3. CONSUMPTION AND UTILIZATION OF LEAF NITROGEN FOR THE NITROGEN OF SHELL

The classical review of Hiratsuka (1920) and a relatively recent work of Horie *et al.* (1978) reveals the efficiency of leaf nitrogen utilization by the larvae of *B. mori.* Over 60 % of the ingested nitrogen is digested and absorbed and about 65% of digested nitrogen is utilized by the 5th instar larvae for silk protein synthesis. This general quantification is for bivoltine races.

The effects of graded levels of protein in the diet on larval growth and silk production have been demonstrated by several workers (Ito and Tanaka, 1962; Ito and Mukaiyama, 1964, 1970; Kamioka *et al.*, 1971; Horie *et al.*, 1971; Horie and Watanabe, 1983 b). The observations of these authors suggest that an optimum level of dietary nitrogen accelerates larval growth and silk production, the best performance is found with highly nutritive proteins. A comprehensive information on nitrogen utilization by *B. mori* has been obtained from the works of several workers (Hiratsuka 1917; Fukuda 1951; Nakano and Monsi 1968).

A sex-specific compartmentalization of nitrogen utilization for cocoon shell and egg production by the 5th stage larvae of *B. mori* reared on mulberry leaves has been demonstrated by Horie and Watanabe (1986). The amount of ingested and digested nitrogen converted to shell was 46 and 70% for the male and 43 and 63% for the female. This clarifies that under optimum life conditions the efficiency of conversion of nitrogen in the shell is very high in the silkworm.

The study of Subba Rao et al. (1989) provides an excellent evidence of nitrogen utilization by the multivoltine Nistari race of B. mori during both favourable and unfavourable seasons. When the larvae were reared on mulberry leaves fortified with variable concentrations of protein meal (1-10%), 1-3% protein enrichment yielded good result. Further, fortification with a 3% protein meal showed a very low nitrogen utilization during the unfavourable season(July-September), but the utilization was several times higher during the favourable season (November-December). The authors implicated higher ambient tmeperature during unfavourable season to the low nitrogen utilization. A low digestibility of protein and efficiency of conversion of digested protein into cocoon shell have been obtained by Shen (1986) at 30°C rearing temperature than those recorded at 20°C.

Utilization of nitrogen by other lepidopteran larvae has been related to the water content of food. A limiting effect of low leaf water on the nitrogen utilization has been clarified by Scriber (1977) in Hyalophora cecropia. Lrvae which were fed leaves low in water, grew more slowly and were less efficient in plant nitrogen utilization than those larvae fed with leaves supplemented with water. This was equally true for both nitrogen utilization efficency and relative accumulation rate of nitrogen. Scriber and Slansky(1981) reviewed the relationship of leaf water and nitrogen with the nutrition of folivore larve belonging to 25 species of Lepidoptera. They concluded that the two nutrients under laboratory conditions predict upper limits for larval performance. Nutritionally unbalanced protein may also reduce larval growth rate by imposing a metabolic load as advocated by Slansky and Scriber (1985) and Schroeder (1986). These authors emphasize that excess protein with accompanying low water in the diet reduces nitrogen utilization. Schroeder (1986) further explained that in such situation excess protein instead of contributing to conversion of larval biomass, added up to metabolic costs for increased catabolism and nitrogen excretion.

Martin and Van't Hof (1988) further emphasized that the reduced efficiency of conversion of digested nitrogen into larval biomass under low dietary water was due to limitation in the amount of water available for the synthesis of new hydrated tissue, and reduced efficiency was not due to the imposition of higher food processing cost . Timmins _et al._ (1988) opined for _Manduca sexta_ larvae that both higher and lower water than normal lead to increased costs in food processing and lower the efficiencies of conversion into larval biomass.

With this background of knowledge and considering t commercial aspect, consumption and utilization of leaf nitrog for the nitrogen of shell by the Nistari race of B. mori duri wet part of summer in West Bengal at different leaf-moisture ha been attempted for investigation.

2.4. LARVAL BODY WATER AND FAECAL WATER WITH REFERENCE TO LE MOISTURE

A chronological change in the percentage of body wat has been recorded from the first to the fifth instar larvae of mori. The lowest amount exists immediately after hatchin increases considerably with the resumption of feeding, almost steady state is maintained from second to fourth instar. T highest percentage is attained in th newly moulted fifth stag but declines considerably towards the end of th stage(Hiratsuka, 1917; Ueda and Suzuki, 1967). Thus the fir instar appears to be the period of water accumulation and t fifth stage is the period of dehydration.

Legay (1957) observed that the larvae of B. mori fed wi mulberry leaves containing 70% water retained much of t ingested water. About 30% was passed out with faeces, 10% w lost as vapour and 60% was retained.

Evans (1939) stated that lepidopteran larvae supported on high-water leaves (>60-90%) abosrbed relatively little from the ingested food water(20-30%), while on low- water leaves (<60-<50%) absorbed much of the ingested food water (60-80%).

Delvi *et al.* (1988) obtained a corroborative result in *B. mori* and *Philosamia ricini* through their food ration experiment. The larvae retained higher amount of dietary water by increasing water retention efficiency from 22% at 100% ration to 61% at 25% ration. In none of the insects, irrespective of ration level, absorption of water was influenced. But in *Danaus chrysippus* increasing ration level boosts up dietary water intake, absorption and retention (Pandian *et al.*, 1978). Thus, lepidopteran larvae have evolved either to the strategies for adapting against water constraints by absorbing higher amount of dietary water or by increasing the efficiency of retention.

Moisture loss is controlled in insects to maintain the balance at an appropriate level depending on the ambient situation and conserved or eliminated according to the state of hydration in the body (Chapman, 1972). In India investigation on water balance in other phytophagous lepidopterans has also been undertaken. Goel and Singh (1987) observed in *Lymantria marginata* that the moisture in the body and egesta decreased with the increase in larval biomass in successive instars. In *Trabala vishnu* the relationship between food water and larval body water

112744 12 FEB

was positively significant (Krishna Rao and Goel, 1987). Similar result was obtained in one multivoltine race of B. mori during rainy season (Pathak and Vyas, 1988). The authors further relate high body water to excessive urination by the spinning larvae during this season. The rate of urination is enhanced by climatic conditions. High rate of urination during rainy season by multivoltine silkworm was earlier recorded by Kumararaj (1969)

Larvae of B. mori have only diuretic hormone secreted from brain neurosecretory cells. The secretion of diuretic hormone is more during rainy season. Therefore, the diuretic hormone controls osmoregulation of spinning larvae of B. mori (Pathak, 1991). Nicolson (1980) and Nicolson and Miller (1983) have made significant study on the hormonal control of diuresis in butterflies. Vyas (1991) recently examined the effects of some drugs on diuresis of a multivoltine hybrid silkworm.

Thus, during rainy season there is high ambient r.h. and more accumulation of larval body water from high-water leaves causing to pass excess moisture with faeces. Excess mositure o the faeces further adds to rearing bed moisture. The conditio favours the growth of micropathogen population, particularly tha of bacteria, which causes considerable crop loss. Inorder t mitigate all these problems and resultant loss the presen investigation has been designed using variable leaf moisture.

2.5. REARING RESULT

In the tropical conditions of India, apart from some genetical relevance of silkworm races, most ot the works on rearing results have so far been concentrated on the impact of different mulberry cultivars on this or that bivoltine or multivoltine breeds or races of *B. mori*. A comprehensive information regarding varietal contribution of mulberry leaves to larval growth and economic characters of silkworm is available from Yokoyama (1963), but the information is on bivoltine breeds or races. The differential nutritive value of the same mulberry cultivar has also been recorded on different seasons, and even depending on the agro-practices.

Apart from other nutritional qualities of leaves, water content surely has a bearing on the rearing results as because the water percentage of mulberry leaves, irrespective of cultivars, differs in different seasons (Pathak and Vyas, 1988; Sinha *et al.*, 1993) and at different ages (Kawase, 1914; Hiratsuka, 1917). Some of the important works on the impact of mulberry varieties can be referred to Krishnaswami *et al.*.(1970a), Tayade and Jawale (1984), Sharma *et al.* (1986), Tayade *et al.* (1988), Das and Vijayaraghavan (1990).

Giridhar and Sivarami Reddy (1991a) reported differential larval weights and cocoon and shell characters of bivoltine breeds on different seasons, the best performance was on rainy season irrespective of mulberry varieties. Further, a highly significant interaction between mulberry varieties and seasons was obtained in respect of both ERR No and ERR Wt (Giridhar and Sivarami Reddy 1991b).

With regard to leaf age and consequent rearing results Krishnaswami et al. (1970b) undertook investigation. Top tender leaves, including buds were found to be superior to lower leaves. Even, if the mature middle or bottom leaves were sprinkled with water prior to feeding, ERR No and ERR Wt were depressed. But the tender leaves are not available in bulk and are not suitable for late-aged larvae for increased larval and pupal mortality particularly during the rainy season.

Because of differences in nutritive value of mulberry cultivars, both cocoon yield and mean cocoon weight vary (Penkov et al. 1988), and also the cocoon weight and shell weight (Periaswamy and Radhakrishnan, 1985).

A study was undertaken by Narayanaprakash et al. (1985) using artificially depleted water in mulberry leaves. The experimental 5th stage larvae were a bivoltine hybrid and a multi x bi cross breed. The larvae were fed with both tender and mature leaves having differential water percentages. Depending on the age and water content of leaves there was considerable variation in the cocoon-shell weight. In general, bivoltine hybrid thrived well on tender leaves and spun larger cocoons while the cross breed thrived on mature leaves and produced heavier cocoons.

Besides the variation in water content, the nitrogen contents, particularly some amino acids such as methionine, histidine and threonine of mulberry leaves of different cultivars vary at different seasons. Thus, Machii and Katagiri (1990) found a seasonal cultivar dependant shell productoion efficiency in the same race of B. mori positively correlated with the amino acid contents.

Nistari race reared on mulberry leaves enriched with 1% protein meals showed a significant increase in ERR no during August-September (unfavourable season). Whereas, during November-December(favourable season) an enrichment with 1-3% protein meal yielded variably an improved rearing performance in respect of larval wt, ERR no, ERR wt, Cocoon wt, shell wt, SR% and absolute silk content (Subba Rao et al. 1989).

Schroeder (1986) reported that when the fifth stage larvae of leaf-eating lepidopterans were fed with mature leaves having low water but fortified with protien, showed lower ingestion rate and growth efficiency but higher apparent digestion efficiency and apparent assimilation rate. Treated larvae pupated at a lower weight. The low leaf water acted as primary limiting nutrient so that surplus protein imposed a metabolic load on larvae perhaps by increased catabolism and excretion of excess amino acids causing osmotic imbalance. Slansky and Scriber (1985) are also of the same opinion.

Fifth stage larvae alone consume about 87% of the total leaf consumption during larval life. The ingestion of high-water leaves raises larval body water at directly proportional level, leading to proportionately increased urination, consequent disease induction, hence, larval and pupal mortality. However, there is no information on effective remedy for crop loss during rainy season. This justifies the present investigation aiming at finding out the rearing performance at different dietary water levels.

2.6. COCOON MELTING

Cocoon melting is the death of pupa and followed by decomposition within the shell enclosure. This is affected by factors such as climatic conditions during larval spinning (Krishnaswami, 1986; Benchamin and Nagaraj, 1987) and during the fifth larval stage of rearing. Seasonal climatic conditions also affects cocoon melting. High humidity and relatively high temperature during rainy season result in highest percentage of cocoon melting (as experienced by farmers and at the Silkworm Seed Production Centres.). However, the literature on cocoon melting is very scanty. Compared to bivoltine breeds less melting occurs in the multivoltine races (Benchamin and Krishnaswami, 1981a, b). The authors further observed among the bivoltines a breed - specific variation in melting percentage.

Giridhar _et al._ (1990) undertook an investigation on melting using different bivoltine breeds of silkworms, reared on different mulberry cultivars and in different seasons. Their results revealed maximum melting during rainy season among Japanese races than the Chinese races and on a particular mulberry variety (S4). Rao _et al._ (1990) also observed a differential melting percentage (2.8 to 5.1%) among four bivoltine breeds reared on the same mulberry cultivar.

No scientific information is available regarding the precise causes of cocoon melting, particularly from the physiological and or consequent pathological stand point. Neither there is any scientific study on this aspect on the multivoltine Nistari. But large scale rearing is required both for silk production and seed production. The density of larvae in a large rearing population in case of practical sericulture adds up moisture in the rearing bed particularly during the rainy season. The overall situation may favour the incidence of carried over diseases in the pupae causing melting.

The present attempt is intended to find out a solution for reducing the pupal melting using leaves containing suitable amount of water.

2.7 REPRODUCTIVE PERFORMANCE

Reproductive function of insects is the result of interaction of nutritional, hormonal and environmental factors (Engelmann, 1970; Calow, 1973; De Wilde and De Loof, 1973 a,b). The fertility and fecundity are very sensitive to quantitative and qualitative changes in the food of silkworms and thus nutrition affects both egg number and egg vigour (Legay, 1958). It is also evident from the experiments on fifth instar larvae of *B. mori* by way of food rationing(Radhakrishna and Delvi, 1987; or by restricting the feeding regimes including feeding frequency/day (Haniffa *et al.*,1988), deprivation of food on different days (Radhakrishnan *et al.*, 1985) or even on different hours of a day (Mathavan *et al.*, 1987) that the nutritional regulations affect considerably the reproductive performance of *B. mori*. All these works perhaps aimed at economizing rearing labour and mulberry leaf quantity.

Observation on different bivoltine and multivoltine breeds of *B. mori* by Pillai and Krishnaswami (1989) under tropical conditions revealed that variation in fecundity was influenced by both intrinsic factors of the breeds and ambient conditions.

A mulberry variety dependent fecundity has been advocatec from the observation on variable number of egg production ir

B. mori (Nacheva *et al.*, 1988). Similarly foood quality dependent egg production has also been claimed in other phytophagous insects (Muthukrishnan and Pandian, 1987).

B. mori like many other lepidopterans having non-feeding adult stage, stores abundant food resource largely during the last larval instar. For the purpose,the last stage attains ' critical weight ' through its early part of essentioal or obligatory feeding period. This feeding pertains largely to reproductive resource allocation (Inagaki and Yamashita, 1983, 1986).

In relating fecundity to pupal weight of *B. mori* Tanaka (1988) advocates that an optimum range of cocoon weight results in maximum egg production, higher cocoon weight causes greater mortality and production of increased number of unfertilized egg-laying moths. Watanabe (1961) and Yokoyama (1973) are of the opinion that the heterosis in egg production among the breeds is not influenced by mere body weight. Watanabe (1961) further proposed the term ' Luxuriance ' on the relation of higher pupal weight to fecundity. Apparently, a high significant posititive correlation exists between the moths reulting from heavy pupae and their fecundity not only in multivoltine breeds of *B. mori* (Rahaman *et al.*, 1978; Jayaswal *et al.*, 1991) but also in other sericigenous moths such as *Antheraea mylitta* (Siddique *et al.*, 1985), *Philosamia ricini* (Singh and Prasad, 1987) and *Samia cynthia ricini* (Nagalakshmamma *et al.*, 1988; Kotikal *et al.*, 1989).

A contradictory result has been claimed by Narasimhanna (1988) that the egg laying efficiency is reduced in those moths obtained from heavy pupae.

However, male pupal weight has no correlation with the fecundity (Gowda et al., 1988). Jayaswal et al. (1991) studied the fecundity of a newly evolved A-25 multivoltine breed at three different seasons in the plains of West Bengal. The fecundity was directly proportional to the female pupal weight, though the average fecundity per range of pupal weight was not constant in all the seasons. A seasonal variation in the fecundity has also been reported by Tazima (1958).

A study on the Nistari race of *B. mori* by Subba Rao et al. (1989) reared on mulberry leaves fortified with protein meal reveals that the larval growth and consequent fecundity results are season dependant. In general the fecundity increases upto an optimum level of protien addition, but the increase is several times higher during favourable seasons (November-December) than that during unfavourable season (July-September).

The foregoing survey of literature reveals a diversity of opinion regarding pupal weight and fecundity of resultant female moths. The luxuriant vegetation, high moisture and endurable temperature during the wet part of summer provide a congenial condition for gaining high larval and pupal weight rapidly. This apparent body weight and good fcundity turn into overall less recovery of eggs due to high rate of larval and pupal mortality and failure of the female moths to mate and oviposit optimally. However, no information is availale regarding abatement of such losses if the larvae are fed with mulberry leaves having depleted water during wet part of summer in tropical regions. This justifies the undertaking of present investigation.

2.8. REELING CHARACTER OF COCOON AND SILK FILAMENT CHARACTER

In tropical humid situation silkworm larvae acquire high dietary water and accumulate the same in body because of low transpiratory loss. Thus, during rainy season a higher amount of urination occurs, which is directly proportional to the leaf water and body water (Pathak and Vyas, 1988). Excess urination causes higher proportion of yellow-stained cocoon production. Such cocoons incur considerable economic loss by way of poor reelability of fibres due to frequent breakes, more droppings and increased waste percentage of fibres leading to increased renditta value (requirement of green cocoons in Kg. to produce one Kg. of raw silk) (Kumararaj, 1969; Kumararaj, 1972).

The filament caharacters such as filament length and denier (fibre thickness) obtained from a particular silkworm race have been implicated by several workers to different mulberry cultivars (Hassanein and El Shaarawy, 1962b; Periaswami and Radhakrishnan 1985; Penkov <u>et al.</u>, 1988). The impact of filament characters may be due to differences in nutrition obtained from different cultivars.

Absorbed urine being alkaline, dissolves the sericin coating of a silk filament, thus exposes core fibroin fibre (Tanaka, 1964; Kumararaj, 1972).

An elaborate study has been made by Tsukuda et al. (1989) on the impact of absorbed moisture on the fibroin component of a silk filament. They examined the fibroin fibre by thermomechanical analysis, X-ray diffractometry and on the basis of refractive index and strength elongation measurement. Increased moisture absorption causes a decreased birefrigence of silk fibre and elongation strength and thus induces filament break during reeling.

With a view to combat excessive urination by the spinning larvae attempts have been made to exploit endocrine mechanism underlying diuresis. Pathak (1991) observed in a multivoltine hybrid silkworm that the brain neurosecretory cells producing diuretic hormone are influenced by high ambient humidity. In the same hybrid silkworm Vyas (1991) undertook both in vitro and in vivo studies using diuretic hormones. The work was aimed at reducing water accumulation in larval body through the enhancement of early urination in pre-spinning larvae for reducing cocoon staining. The author foud 5- hydroxytryptamine a promising hormone.

The present investigation is an attempt to understand whether the differential nutritional efficiency under different dietary water levels affect the silk filament characters and damage due to excessive urination could be ameliorated.