REVIEW
OF
LITERATURE
REVIEW OF LITERATURE

Insect nutrition concerns more than mere dietetics. It involves many metabolic processes. It is a link between physiologic and ecologic phenomena associated with natural selection and competition for food (Casey, 1976). Plants with their co-evolutionary existence with herbivorous insects have attempted to evolve chemical strategies to defend against phytophagous insects. The subject of plant chemical ecology may be considered to have been developed to answer a few questions raised in as early as 1950s by the more and more frequent discoveries in higher plants of complex and varied natural products. What is the purpose of producing varieties of several kinds of secondary metabolites? Fraenkel (1959) opined that these so called secondary metabolites could not be accommodated by the idea that they are simply "waste products" of primary metabolism, accumulating in the plant cell because of the absence of an efficient excretory system. Instead, he described these metabolites as "trigger" substances, which induce or prevent the uptake of nutrients by the herbivore.

Ehrlich and Raven (1964) were among the first to propose a defined ecological role for plant products as defense agents against insect herbivory. They propose that through the process of co-evolution, insects are able to detoxify certain chemicals so that, eventually, they may become feeding attractants. Such a hypothesis helps to explain the relatively restricted feeding preferences of many species of insects, especially the lepidopterans. Therefore research was initiated in several laboratories to test this co-evolutionary theory and to attempt to establish a defense role for secondary compounds.
To this basic theory the role of the defensive secondary metabolites of plants as a source of nutritional supplements has not been tested in a single insect.

The distribution and concentration of secondary metabolites fluctuates during the life cycle of plant, some are localized in the epidermal cells, which will be rapidly detected by the phytophagous insects. There is variation in chemistry of the secondary metabolites, which can occur within the same leaf between the leaves on the same branch or between plants in the same population. Environmental parameters can dramatically alter the concentration of secondary compounds in the leaf tissue. Other important features are the relative solubilities of compounds present and hence their impact on the herbivore the relative stability within the plant (Harborne, 1999).

The complexity of their chemical structures and biosynthetic pathways “natural products” has historically received little attention from most plant biologists. Organic chemist, however have long been interested in these novel phytochemicals and have investigated their chemical properties extensively since 1850s. Interest in natural products was not purely academic but rather was prompted by their great utility as dyes, polymers, fibers, glues, oils, waxes, flavoring agents, perfumes and drugs. They have a highly diverse biological effect, which has prompted a reevaluation of the possible roles these compounds play in plants, herbivores, especially in the content of ecological interactions. Many of these compounds now have been shown to have important adaptive significance in protection against herbivores and microbial infection, as attractants for pollinators and seed-dispersing animals and as allelopathic agents.
Silkworm Nutrition

Silkworm is monophagous and appears to derive all its nutritional requirements from a single plant, *Morus alba*. However, plants *per se* are inadequately equipped with nutrients that put constraints on the consumption, utilization and allocation of food, such that phytophagous insect seldom achieves its potential performance value. With reference to silkworm nutrition, it has been recognized that production of quality leaves increases quantity of ingesta and digesta. It has been realized that nutritional quality of mulberry leaf has greater impact of regulation over the quantum of ingesta, digesta and digestibility of food among silkworms (Ito, 1972). The quantum of ingesta and digesta has direct relation with growth and raw silk production (Takeuchi and Kasaki, 1962). There are good number of reports to indicate that leaf quality improvement by supplementation with various nutritive additives like proteins, amino acids, minerals, vitamins and salts of various organic and inorganic micronutrients.

Protein Supplement

Researches have shown that enrichment of mulberry leaves through fortification with proteins improved cocoon quality and quantity. Supplementary feeding in *B. mori* results in increase in concentration of haemolymph protein (Nagata and Kobayashi, 1990; Krishnan *et al.*, 1995; Janarthanan *et al.*, 1999), larval body weight, silk gland and cocoon weight (Sarkar *et al.*, 1995; Vanishree *et al.*, 1996).

The importance of nutrition during larval development and the rate of silk protein synthesis by the supplementation of optimum dose (2 and 4mg.) of protein P-Soyatose (soyabean protein) sprayed to the mulberry leaves,
irrespective of sex, the fifth instar silk worm, *B. mori* registered maximum increase of the larval (3.553gm.), silk gland (0.991gm.), cocoon weight (1.998gm.), pupa (1.619gm.) and shell (0.379gm.) as well as significant increase in protein synthesis (Ito 1981; Krishnan et al., 1995, Nirmala et al., 1996; 2002; Janarathan et al., 1999). Of the various additions, dietary protein has significant impact on the silk worm growth and development (Ito and Tanaka 1962; Ito and Arai, 1965; Kamioka et al., 1971; Giridhar and Radha, 1986). Sarkar et al., (1995) demonstrated that the growth and weight of silkworm larvae, total protein content of silk gland were significantly increased, whereas total lipids and carbohydrates decreased when fed with mulberry leaves supplemented with soya milk, vitamins and potassium iodide. Supplementary feeding in *B. mori* resulted in increased concentration of haemolymph protein (Nagata and Kobayshi 1990; Krishnan et al., 1995; Janarthanan et al., 1999), larval body weight, silk gland and cocoon weight (Sarkar et al., 1995; Vanishree et al., 1996).

**Amino Acids Supplement**

There are reports to indicate that 2 percent neutralized aspartic acid sprayed mulberry leaves, fed to the fifth instar silk worm, *B. mori* resulted in improvement of larval growth, economic characters of silk worm, significant reduction in the larval duration (Kabila et al., 1994; Horie et al., 1966; Harper, 1977; Ito and Inokuchi, 1981; Rai et al., 2002). Similarly, it has been shown that amino acids such as aspartic acid, glutamic acid are essential for silkworm growth (Ito and Inokuchi, 1981). Ito (1967) demonstrated that nutritional role of nonessential amino acids like alanine, glycine and ferine are required less in presence of aspartic acid. Increased concentrations of
aspartate and glutamate improved fecundity in silk moth, hatchability of eggs, as well as filament length, denier and other organic food reserves of the silkworm larvae.

**Mineral Supplement**

Supplementary feeding in *B. mori* resulted in increased concentration of haemolymph protein (Nagata and Kobayashi, 1990; Krishnan *et al.*, 1995; Janarthanan *et al.*, 1999), larval body weight, silk gland and cocoon weight (Vanishree *et al.*, 1996). Sarkar *et al.*, (1995) reported that the growth and weight of silkworm larvae and total proteins of silk gland increased significantly, whereas water content, total lipids and carbohydrate content decreased when larvae were fed with mulberry leaf supplemented with combination of three nutrients, soy milk + vitamins + potassium iodide salt. Application of micronutrients to mulberry leaves improved all the economic properties of the cocoon as well as cocoon quality and quantity (Ito and Niminura, 1966; Hori *et al.*, 1967; Viswanath and Krishnamurthy, 1982; Lokanath and Shivashankar, 1986; Benjamin and Jolly, 1987). Kaliwal (1996, 1998 and 2005) and his associates have demonstrated that multi mineral treatment of mulberry leaf fed during silkworm development increased total protein, glycogen and improved cocoon parameters (Nirwani and Kaliwal, 1996; Hugar *et al.*, 1998; Arundhati *et al.*, 2005). Similarly, Dasmahapatra *et al.* (1989) reported that the enrichment of mulberry leaf with salts of potassium, cobalt, Calcium had significant effect on silk protein as well as on cocoon shell weight. Mulberry leaves dipped in rain water containing rich amount of trace elements stimulated the metabolic activity of fifth instar, *B. mori* (Thangavelu and Bania, 1990). Supplementation of mulberry leaf with
potassium sulphate and zinc chloride increased fat body glycogen (Nirwani and Kaliwal, 1996; Hugar and Kaliwal, 1998). Singaravelu, et al., (2004) reported that oral supplementation of micronutrients, magnesium sulphate with different concentrations, from 1 ppm to 3 ppm through mulberry leaves to fifth instar, B. mori improved fecundity, hatchability, filament length, denier and other fuel reserves.

Vitamin Supplement

Artificial diet when fortified with vitamin C has been demonstrated to improve growth and cocoon characters and act as phagostimulant and should be added to artificial diet (Ito, 1961a and b). Young larvae reared in 1.5 percent ascorbic acid enriched mulberry leaves resulted in higher silk length, weight and denier (MadhuBabu, et al., (1992). Cui, et al. (2003) reported that vitamin C addition to artificial diet stimulated growth in young silkworm larvae. Chauhan, et al. (1992) demonstrated that the mulberry leaves treated with 10 percent ascorbic acid (vitamin C) and then fed to different aged larvae enhanced egg laying capacity of the female moth. Sarkar, et al. (1995) demonstrated that the growth and weight of silkworm larvae, total protein content of silk gland were significantly increased, whereas total lipids and carbohydrates decreased when fed with mulberry leaves supplemented with soy milk, vitamins and potassium iodide. Mathavan, et al. (1985) reported that caffeine and theophylline, two secondary plant metabolites when administered through food significantly reduced the reproductive potential and protein content of ovary of the silk moth. It was demonstrated that mulberry leaves fortified (by dipping) with ascorbic acid (2% and 3%) shade dried and fed to the fourth and fifth instar silkworm demonstrated significant
improvement in cocoon characters in 2 percent followed by 3 percent respectively in all the three races tested for (Senagupta, et al., 1972; El-Karaksy and Idrisis, 1990; Madhubabu, et al., 1992; Rajendra Prasad 2004).

Ascorbic acid is an indispensable nutrient for the growth and development of many insects, act as a phagostimulant (Ito, 1961). Absence of ascorbic acid in the diet of first and second instar B.mori resulted in poor growth and development.

The diet of first and second instar B. mori resulted in poor growth and development from third instar onwards (Ito and Arai, 1965). First and second instar silk worm reared on 1.5% percent ascorbic acid enriched leaves resulted in higher silk yield and denier values (Madhubabu, et al., 1992). Rai, et al., (2002) reported that oral administration of folic acid with mulberry leaves to the first day of fifth instar B.mori (PMxNB

D

2

) at 0.5mg/ml., once a day till the onset of spinning of cocoon has gained the larval weight (3.61-3.8 gm.) with substantial reduction in larval duration and resulted significant increase in the economic characters such as weight of cocoon (12.2%), shell (21.9%), silk filament length (17.8%), weight (23%), denier (45%) and significant increase in fecundity (32.6%). Folic acid is a compound made up of the petridine nucleus P-aminobenzoic acid and glutamic acid (Harper, 1977).

In B.mori, Horie, et al. (1966) have reported that the requirement of some of the B vitamins for its normal growth and development. Ascorbic acid is an indispensable nutrient for the growth and development of many insects, act as a phagostimulant (Ito, 1961). Absence of ascorbic acid in the diet of first and second instar B.mori resulted in poor growth and development from third instar onwards (Ito and Arai, 1965). First and second instar silk worm reared
on 1.5 percent ascorbic acid enriched leaves resulted in higher silk yield and
denier values (Madhubabu, et al., 1992). Etebari, et al. (2004) reported that,
high dose of vitamin B₃ (Nicotinamide) in fourth and fifth instar bivoltine hybrid
silkworm diet by dipping/soaking for 15hrs. once a day interrupts larval
feeding and normal growth. There was high mortality of larvae during
moultng. As the concentration of vitamin B₃ was increased from 1 to 3gm. per
larvae the larval weight was decreased (48%) and the duration of the larvae
increased. But there was increase in concentration of uric acid in haemolymph
demonstrates hyperuricemia, the biochemical compounds show significant
decrease without affecting sodium and potassium and glucose concentration
in the body of larvae. The treated larvae exhibit nicotinamide hypervitaminosis
symptoms such as immobility, dyspepsia, darkening of skin, inability to
excrete normally, excreting brownish fluid and swelling of rectal muscles.
Increase in concentrations of ascorbic acid in the diet, there was decrease in
the yield (Etebari, et al., 2004). The same effect with multivitamins (Saha and
Khan, 1996). Nutritional interactions exist between vitamin B₃ and other B
group of vitamins (Chang and Li, 2004). The vitamin B₃ is essential for cellular
respiration, release of energy, metabolism of protein, carbohydrate and lipids
in the form of co-enzymes nicotinamide adenine dinucleotide (NAD) and NAD
phosphate (NADP), where it acts as electron acceptor or hydrogen donor in
biological redox reactions (Alhadeff, et al., 1984; Swendseid and Jacob,
1994). This vitamin is essential for appropriate growth of larvae and
reproduction in insects (Ishii, 1971; Yazgan, 1972; Baker, 1975; Jang, 1986;
Ritter and Johnson, 1991; Lewinson, et al., 1992; Ozalp and Emre, 1992;
Chang and Li, 2004).
Plant Growth Regulators  
There are good numbers of reports to suggest that plant growth regulators also influence over-all nutritional physiology of silkworms. Nair, et al., (1997) reported that, the effect of abscisic acid (ABA), a sesquiterpenoid plant hormone in different concentrations (0.1 to 5ppm.) were topically applied and individually administrated orally through mulberry leaves of the different batches of fifth instar silkworm (PMxNB4D2) at 24, 48, 72 and 96hrs. resulted substantial increase in the major economic traits in topically treated groups, whereas 5ppm. ABA through oral treatment at 48hr. silk worm larvae resulted in highest improvement in cocoon and shell weight, without affecting the feeding period, shell ratio, filament length and denier. It has been suggested that ABA accelerated the rate of DNA synthesis and enhanced the economic characteristics of silkworm. Topical supplementation of ABA at 1, 2 and 5ppm. increased the larval weight significantly when treated at 72hrs., but the same was true when administrated orally at 48hrs at 0.2ppm. Earlier reports mentioned that phytohormones like Indole acetic acid (IAA), gibberlic acid (GA3), Indole Propionic acid (IPA), Indole butyric acid (IBA) at low concentrations administration exhibited significant increase in silkworm larval weight (Kamada and lto, 1984' Magadum and Hooli, 1989; 1990; 1991a and b; Shantkumari; et al., 1989). However, high concentrations of ABA (6-60mg/1000ml distilled water) to grass hopper, Aulocara ellioti or in Sarcophagi bullata affected the vitellogenesis and fecundity, but still higher concentration did not cause any effect (Visscher, 1980; De Man; et al., 1981). In silkworm low concentration of ABA at critical period of larval development can act as growth stimulatory agent like juvenile hormone (EDIT and Little, 1970). At
24hrs. of the larvae the topical treatment of ABA resulted significant increase in cocoon weight, without extending the larval duration, 0.5ppm. ABA administrated orally resulted maximum increase in shell weight. Visscher (1980; 1982) reported lower doses of GA3 increased longevity and egg viability in grasshopper, phytohormone IAA, GA3, IBA, IPA improved the economic traits in silkworm, support the supplementation of ABA for improving yield parameters in silkworm and phytohormones alter the rate of DNA synthesis.

Shantakumari et al., (1989) reported that gibberlic acid (GA3) sprayed mulberry leaves (100μg/ml) fed to the hybrid silkworm larvae B.mori L. starting from first day of third instar till spinning stage improved significantly the body weight of larvae, fecundity and several important economic cocoon parameters.

Plants Secondary Metabolites

Rajashekhargouda et al., (1997) reported that, the petroleum ether extract (1000μg/larvae) aqueous extract (10%) of Tribulus terrestris L. and Psoralea coryleifolia spray on 48hr. old fifth instar silk worm B.mori (PMXNB4D2) extended the maturity of the larvae by 22hrs, and the latter accelerated the maturity by 6 hrs, resulting an increase of 12.76 percent and 15.07 percent in cocoon yield whereas the aqueous extract of the test plants affected early maturity by 6hrs. with an increase of 4.84 percent in cocoon yield in the field trial. Tribulus terrestris, Psoralea coryleifolia plant extracts exhibited JH mimic activity on silkworm and also extended the fifth instar larval life by a day and feeding period resulted bigger sized cocoons. Rajeshwari and Isaiarasu, (2004) reported that 1 percent w/v dietary
supplementation of leaf, flower and pod aqueous extract (by leaf dip method) of *Moringa oleifera* on the fifth instar silk worm (PMxNB4D2) showed significant increase in larval and cocoon parameters weight of ovariole pupa and eggs number. Among the extracts from three portions of the *Moringa oleifera* plant, the leaf extract was more effective followed by flower and pod extracts, which has improved the growth and reproductive parameters. *Tribulus terrestris, Phyllanthus niruri, Boerhavia diffusa, Psoralea corylifolia, Caesalpinia coriaria* and *Parthenium hysterophorous* in the silk worm *B. mori* (Murugan et al. 1998). Reserpine, an alkaloid isolated from the roots of the *Rauwolfia sepentina* act as a neurotransmitter influencing the metabolism of glycogen and trehalose during fifth instar *B.mori* (Sujatha and Rao, 2003). Narayanaswamy et al. (2005) investigated that the influence of enriched mulberry leaf with Kohiko silcare feed supplement (1000g / 100 DFLs) on growth of larva, mature larval weight, lower larval mortality, shorter fifth instar duration, total larval duration, economic characters of cocoons, and silk characters of CSR silkworm *B. mori* L. were significantly high. However rearing of fifth instar worms on mulberry leaf enriched with soyabean flour has also resulted in higher larval, cocoon and silk parameters (Sundar Raj et al. 2001). Foliar application of micronutrients either single or in combination increases all the quantitative and qualitative parameters of leaf (Vishwanath, 1996). Foliar application of *Daman penshibao* increased all the economic characters of mulberry leaf (Jyothi, 2000).

Shoukry (1996) reported that topical application of two volatile oils obtained by steam distillation process of *Matricaria chamomilla* flowers and *Clerodendron inerme* leaves 76µg/fly and 84µg/fly respectively on the
biology of adult house fly *Musca domestica* have greatly affected all biological parameters such as larval, pupal duration, pre-oviposition period, fecundity, fertility, hatchability and longevity of adults were reduced. And there was significant increase in larval and pupal mortality. The two-volatile oils contain terpene group, which may consider as insect growth regulators (IGRs) in their properties and action (Shoukry, 1996). Mathavan* et al.* (1985) reported that effect of secondary plant metabolites (Caffein and Theophylline) at 0.1 percent and 0.2 percent administrated through food significantly reduced the reproductive potential (ovary length and egg number) and protein, energy contents in the eggs of silk moth *B.mori*. However, the fat content remains almost constant in the eggs of control and experimental animals. The secondary compounds of plants with few exceptions, serve primarily as a defense system to discourage herbivory (Ehrlich and Reven, 1964). The alkaloids such as caffeine, theophylline and aminophylline posses’ antifeedant properties and interference in growth and reproduction (McDaniel and Berry, 1974; Srinivasan, 1977). These secondary plant substances reduce the rate and efficiency of food utilization (Muthukrishnan* et al.* 1979; Premalatha, 1982). Because of antifeedant nature of caffeine and theophylline, the starved larvae utilize haemolymph protein as a source of energy for maintenance (Mills et al., 1966). Singh and Rao (1999), reported that applications of various organic solvents soxhelet extract of dried leaf powder of *Artemisia vulgaris* plant has not possessed any antifeedancy when leaves painted with crude extract but cause only inhibition of ovarian development in fourth and fifth instar nymphs of *Schistocera gregaria*, while in sixth instar (0-24hrs. old) *Spodoptera litura* both reproduction and development process were affected.
when both the larvae were treated topically with petroleum ether leaf extract, at the dose of 112 and 224μg/nymph. However, topical application of ethanol extract of test plant leaf at the dose of 101.4μg/nymph of fifth instar S. gregaria and S. litura affected ovarian development. Hexane extract of stem test plant at the dose of 400μg/nymph did not cause any effect on mortality, nymphal period, adult emergence and ovary development. But the effect of some hexane fractions on sixth instar (0-24hrs.old) S. litura at the dose of 200μg/larvae affected for pupation and adult emergence. Topical application of the diethyl ether fraction on 0-24hrs. old fifth instar nymphs at the dose of 210.8μg. residue/nymph showed no effect, but the nymphal mortality (46.7%) was observed when the dose was increased. The same fraction by topical application on sixth instar (0-24hrs. old) S. litura at the dose of 210.8 and 421.6μg/larvae did not cause any adverse effect. However, the Chloroform fraction by topical application at the dose of 312μg. in fifth instar nymph of S. litura did not cause any morphogenetic effect but other species of the test plants were reported to carry antifeedent activity against larvae of Pieris rapae (Yano and Kamimura, 1993). Fourth instar Crocidolomia binotalis (Facknath and Kawool, 1993). Larvae of Cydia pomonella (Suomi, et al., 1986), S. littoralis. Ghosh, et al., (2004) quantified 20-hydroxy ecdysone from Ipomoea hederacea plant seed powder extract by HPLC. The extract containing 20-hydroxy ecdysone 26 percent w/v was diluted with water sprayed on mulberry leaves and fed the silkworms and observed effect on moulting in B. mori insects, resulted the rate of spinning response was more significant at the dose of (19-38) into 10^4 gm/lit. i.e. significant rate of maturation from 31 to 35 hrs., cocoon and shell weight. It has been reported that exogenous
administration of phytoecdysteroids increase the cocoon yield and enhance the productivity of silkworm rearing with insignificant variations in the quality of cocoon. Application of phytoecdysteroids after third day of fifth instar significantly accelerates the maturation of silkworm races without affecting cocoon characters (Chou and Lu, 1980; Chandrakala, et al., 1998; Shivakumar, et al., 1995). Continuous application of 20-hydroxy ecdysteriods is lethal resulting to high mortality in silkworm larvae (Dinan, 2001; Moriyama, et al., 1970). Sudden rise in ecdysteroid titre terminate the feeding habit at the end of fifth instar and stimulate. Spinning may be the result of accelerated effect on the development of silk gland (Chandrakal, et al., 1998). Nair, et al., (2003) reported that topical application of 1.25ppm. Bakuchiol, a JH analogue from Psoralea corylifolia to the 48 hour old fifth instar silkworm, B.mori at 24, 48, 72 and 96hrs. as a single dose (12.5ml/100 larvae) improved the larval weight (10.68%) and commercial traits such as cocoon (14.55%), cocoon shell weight and significant increase in silk filament length. But 0.625ppm. treatment increased the cocoon weight (9.61%) in case of bivoltine hybrid (PMxNB₄D₂). 1.25ppm. at 48hrs. old bivoltine hybrid improved the cocoon weight (11.82%) followed by enhancement of 8.13 percent and 7.02 percent when treated with 0.625ppm. at 48 and 24hrs. respectively. Cocoon weight (8.46%) followed by 0.625ppm. at same age (7.23%). The pattern of improvement in shell weight was also similar to that of cocoon weight. In 48hrs fifth instar silk worm (PMxNB₄D₂) increase in cocoon weight (11.24%) and (8.33%) with 1.25ppm and 0.625ppm treatment respectively. The shell ratio was increased with 1.25ppm at 72 and 96hrs. Treatment indicated that bivoltine hybrids showed better response than multivoltine hybrid and bivoltine
are more sensitive to the JH analogue than multivoltlines. Others reported that improvement in cocoon, shell weight and administration of minute quantities of JH analogue (Murakoshi, et al., 1972; Chang, et al., 1972; Nair, et al., 1997). Kadam et al. (1988 a and b) reported that foliar spray of 5ppm. of aqueous extract of vipul (triacontanol) on spinach leaves 30 days after sowing resulted an increase in the total protein, essential amino acids and nitrate reductase activity both in vivo and in vitro after 20 days of application.

Insect Hormones of Plant Origin

Many plants known to contain ecdysteroids with high moulting hormone activity in insects (Nakanishi et al., 1966). Various chemicals having ecdysteroids activity observed in species of fern and angiosperms (Imai et al., 1969; Hikino and Takemoto, 1974; Hetru and Horn, 1980). Oral administration of phytoecdysteriods before spinning accelerated and synchronized spinning behaviour (Chou and Lu, 1980). Enhancement in productivity of silkworm rearing by the use of phytoecdysteriods has no effect on the quality of cocoon (Ito, et al., 1970; Chou and Lu, 1980). The ecdysteroids play key role in moulting and metamorphosis in insects. The effect of phytoecdysones on the growth of silkworm and increase in cocoon yield to enhance larval maturation (Ito et al., 1970). Robyn Klein (2004) reported that phytoecdysteroids are a class of bioactive chemicals synthesized by plants illustrates that bridging the study plant science and plant-animal co-evolution which can provide and integrative perspective on plants and human health. These chemicals are used for defense against phytophagous insects which are similar to ecdysteroid hormones produced and used by insects and Crustaceans for moulting (ecdysis). These
phytoecdysteroids have been shown to stimulate synthesis of protein in animals and humans, which have adaptogenic, antimutagenic, hypcholesterolimic, immunostimulating with nutritive tonic properties (Lafont and Dinan, 2003). Rajashekahargouda, et al., (1997) growth promoting effect of the aqueous extract of some plants such as Tribulus terrestris, Phyllanthus niruri, Boerhavia diffusa, Psoralea corylifolia, Caesalpinia coriaria and Parthenium hysterophorous in the silk worm B. mori (Murugan, et al., 1998).

Efficiencies of Conversion of Food

The food consumption has a direct relation on the larval and cocoon characteristics (Shivakumar, et al., 1995) and silkworm breeds (Remadevi, et al., 1992). Anantha Raman, et al., (1993) reported that consumption, digestion, utilization and efficiency of food conversion into larval body of silkworm hybrid (PM×NB4D2) in different instars were significantly different. The approximate digestibility (AD) and efficiency of conversion of ingested food (ECI) reduced in successive instars. The ingesta and digesta in earlier instars were lower (due to small gut) and increased gradually in fifth instar (due to larger gut). Variations were observed in the ingesta, excreta (lower in the first instar, gradually increased in fifth instar) and reference values among the same breed in different instars and season but highest in the fifth instar (longest feeding period). The reference ratio (RR) (Ingesta/Excreta) was high in the first 3 instars and reduced gradually in the late age (low quantum of undigested food substances formed in early instars). The AD, ECI and ECD values were high during first, second and third instar and reduced with advancement of instars due to higher absorption ability and digestibility in the early instars. The low ECD in the fifth instar is due to higher utilization of
digested food for metabolic activities. The ECI and ECD required to produce one gram cocoon were 4.974gm. and 1.880gm. respectively. Production of one gram cocoon shell requires 9.66gm. ingesta and 3.654gm. digesta. Higher ingesta values for forth and fifth instar with different breeds (Ito and Kobayashi, 1978; Hori, et al. (1976) and the same breed in different season (Yamamoto and Fujimaki, 1982). Low feeding rate, nutritional inadequacy of feed or both lead to poor growth (Waldbauer, 1964). Food consumption in the last instar alone was 86.78 percent of the whole ingesta (Hiratsuka,1920).

Rahamathulla (2006) reported that influence of oral intake of an antibiotic (Norfloxacin) through mulberry leaves (50 and 100 ppm.) on feed conversion through efficiency of fifth instar silkworm hybrid bivoltine races (CSR2 x 4) and cross breed (BL67 x CSR106) showed that food consumption of treated group was on par with the control group. However the nutritional parameters such as digesta, approximate digestibility (37.2, 35.7 %) and reference ratio were significantly higher in the treated larval groups and nutritional efficiency of ingested food into larvae assimilation, conversion of food into body substance, cocoon and shell weight were significantly higher in the antibiotic treated larval group. Antibiotic (Norfloxacin) intake does not influence food consumption of larvae (Aftab Ahamed et al., 2001). Proportion of food intake and production of faecal pellets varied (Remadevi et al., 1992). The amount of excreta increased as growth advanced and the production of excreta depends on availability, rate of intake of food, absorption and retention time of food in the gut (Waldbauer, 1964). The efficiency with which consumed food was assimilated varied from species to species of silkworms (Radha et al., 1981). Digestibility is affected by imbalanced diet, high crude
fibre and water deficiency in the feed (Waldbauer, 1964). Higher reference ratio (indirect expression of absorption and assimilation of food) indicate high rate of digestion, absorption of food (Rahamathulla, et al., 2002). The consumption index was lower in antibiotic intake along with mulberry did not enhance the efficiency of conversion of food into body substance. But the efficiency of conversion of ingested food (ECI) to larval body weight was significantly higher (30.95%) in CSR 2 x 4. Increase in food utilization by the antibiotic treated larvae is attributed to increase enzyme activity of nitrogen, minerals and crude fat resulted in vigorous growth of larvae (Shyamala et al., 1960; Verma and Kushwaha, 1971). The ECI and ECD to larval body weight varied depending on variety of mulberry leaves (Anantha Raman et al., 1994). ECI and ECD to cocoon and shell are the efficient parameters in practical Sericulture (Nair and Trivedi, 1998). It is evident from the literature that the nutritional background of the larval stage influences the status of the resulting pupae, adult, and production of the silk.