3. Review of literature

Certain aspects of ecology, diversity and distribution of shade tree, *Alnus nepalensis* have been studied and related literature on these are available. In an article on "Ecology of Himalayan Alder", Sharma *et al.* (1998) had given a review of its taxonomy, distribution, *Frankia*-symbiosis and nutrient cycle that was helpful in understanding the change in physical and biochemical profile of the tree with changing seasons. Literature on its nutrient dynamics (Sharma, 1993), litterfall, decomposition and nutrient release (Sharma and Ambashta, 1987), dry matter production and nutrient cycling in *Alnus*-cardamom agroforestry system (Sharma *et al.*, 1994) are informative. The article "Large cardamom plantation: An age-old agroforestry systems in eastern Himalayas", by Singh *et al.* (1989) helps in better understanding of the basic facts and figures of large cardamom agroforesty. Sharma *et al.* (2000) in the article, "Large cardamom farming in the Sikkim Himalayas: Boon to the mountain people", has highlighted the optimum performance of *Alnus* –cardamom stands in cardamom agroforestry. In this article he states that dry matter production was found to be higher and nutrient cycling faster in agroforestry system of large cardamom grown under Nitrogen fixing alder (*Alnus*-cardamom) compared to mixed tree species (forest-cardamom). The biomass was found to be 28% higher in the *Alnus*-cardamom stand as compared to forest-cardamom stand, thus supporting the choice of *A. nepalensis* as the best shade tree for large cardamom agroforestry.

3.1. Seasonal occurrence and inventory of insects on *Alnus nepalensis:*

Although, from Sikkim there are a few reports on the insect species that attack "Utis tree" (Pangtey and Thakur, 1986 and Phaloura and Singh, 1991, 1992), no literature is available on detailed systematic account of the occurrence of insects or their seasonal incidence on *Alnus nepalensis*.

From Sikkim, the information is generally available in the form of reports on pest outbreaks, short pest descriptions and their natural enemy associations (Pangtey and Thakur, 1986 and Phaloura and Singh, 1991, 1992). In a published article on "Insect pests of large cardamom in Sikkim", Pangtey and Thakur (1986) reported severe defoliation of the tree mainly by a lepidopteran and a coleopteran species.

There are a few reports on defoliation of *A. nepalensis* by insect pest from Nepal (Mulder, 1983; Das and Raychaudhuri, 1983 and Moestrup, 1985) and eastern and central Bhutan (Raman, 1998). Several species of scarabids with two new species were recorded from Nepal on Himalayan Alder (Sabatinelli and Migliaccio, 1982). In the article "Long horned beetle attacking 'Utis' plantations," in Nepal, Moestrup (1985) reported about severe infestation of the tree by these beetles. Defoliation of 'Utis' plantation by a species of Cryptocephalidae, in Nepal was reported by Mulder (1983). Sharpe (1983) reported some mice, voles, grasshoppers and crickets of 'Utis'. Taxonomic notes on aphids from Nepal and India on 'Utis' are available from Quednau (1973) followed by Quednau and

Chakrabarti (1980). Peter (1990) in his article "*Alnus nepalensis* - A Multipurpose Tree for the Tropical Highlands" has also reported about a number of pests of Himalayan Alder. Some of the insects attacking *A. nepalensis* in Nepal and Bhutan were also found attacking the tree in Sikkim.

Besides Himalayan Alder, literature on the other shade trees of high altitude and their insect fauna association gave useful and parallel information, which was helpful in carrying out the current study. Erelli *et al.* (1998) discussed altitudinal patterns in host suitability for forest insects. In an edited book entitled "The biology and management of Red Alder" (Hibbs *et al.*, 1994), information on insects attacking the tree, *Alnus rubra* was available. The book "Introduction to forest and shade tree insects"(Barbosa and Wagner, 1988), provided an idea of the shade tree pests from India and abroad.

3.2. Incidence and natural enemies of major folivores:

It was observed that *Gazalina chrysolopha* and *Chrysomela chlorina* were the major folivores that defoliated *Alnus nepalensis* in different seasons. Earlier reports also labeled *G. chrysolopha* and *C. chlorina* as the major folivores of *A. nepalensis* (Pangtey and Thakur, 1986; Raman, 1998; Phaloura and Singh, 1991-1992). Incidence of *G. chrysolopha* and *C. chlorina,* on *A. nepalensis* has been reported by Raman (1998) and Phaloura and Singh (1992). Pangtey and Thakur (1986) have also recorded the

incidence of *G. chrysolopha* and *C. chlorina* and specially noted that the defoliation of *A. nepalensis* by *G. chrysolopha* was so severe that it affected the shading effect of the tree. Life cycle of *G. chrysolopha* on oak tree in Pakistan, has been worked out by Rehman and Chaudhry (1992) who also reported its caterpillars as serious defoliators. From the temperate zone, similar to that of Sikkim, other lepidopteran, such as winter moth (*Operophtera brumata*) (Pfadt, 1985) and gypsy moth (*Lymantria dispar)* (Speight *et al.*, 1999), were known to attack forest shade trees. Such cases have some resemblance with the nature of depredation caused to Himalayan Alder by *G. chrysolopha.* Similar attacks on the forest tree, *Populus* by *Chrysomela sripta* (Burkot and Benjamin, 1979; Harrell *et al.*, 1982 and Ohmart *et al.,* 1985) at almost similar altitude, are also reported.

From Sikkim, very meager information is available on the natural enemies of *G. chrysolopha.* However, there are a few reports on its natural enemies available from other neighbouring countries. Raman (1998) in his article "Out break of *Gazalina chrysolopha* and defoliation of *Alnus nepalensis* in eastern and Central Bhutan", mentioned about some larval and pupal parasitoids of *G. chrysolopha* attacking *Alnus* tree in Bhutan.

From Sikkim, Phaloura and Singh (1991, 1992) had attempted to study a few natural enemies of *C. chlorina.* However, detailed information on its natural enemies is lacking. In the article, "Coccinellid (coleopteran) fauna associated with Indian alder *Alnus nepalensis*", Phaloura and Singh

(1991) reported seven species of coccinellid preying on the immature stages of *C. chlorine*. This was followed by an article on the biology of *Aiolocaria hexaspilota,* predating on eggs and immature stages of *C. chlorina* from Sikkim (Phaloura and Singh, 1992).

3.3. Population Dynamics of Major folivores:

Since literature on population dynamics of *G. chrysolopha and C. chlorina* is lacking, available information on the insects living in cold conditions and at almost same altitude, defoliating shade trees have been consulted. The incidence of winter moth, *Operophtera brumata* (Pfadt, 1985) is similar to that of *G. chrysolopha*, as the larvae of both these moths are active in winter, defoliating their hosts, the elms shade tree and *A. nepalensis* respectively. Population dynamics and other related matters of the winter moth have been highlighted by Embree (1965), Buse and Good (1996), and Wint (1983). Another work on population dynamics of the lymantriid moth, *Porthetria dispar* is also available from Ramzi (1991).

Some comprehensive reports on population build up of other coleopterans (as that of *C. chlorina*) are available from Rawat and Singh (1980), Banerjee and Nath (1986), Krishnaiah *et al.* (1987) and Chaudhary *et al.*, (2001). These have been cited from time to time to support the findings in present study.

3.4. Population changes and their relation with weather parameters:

G. chrysolopha is perfect example of an insect thriving in cold conditions of Sikkim. Literature on population incidence of Lepidopteran and Coleopteran larvae and their relation with weather parameters, with special reference to thermal tolerance, are available from the works of different authors (Southwood, 1972; Price, 1975,1997; Nayar *et al.*, 1976; Varley *et al.*, 1980; Rawat and Singh, 1980; Miller and Cronhardt, 1982; Wint, 1983; Banerjee and Nath, 1986; Krishnaiah *et al.*, 1987; Hunter, 1993; Kimberling and Miller 1998; Sharov *et al.*, 1999; Koltunov and Andreeva, 1999; Wellington *et al.*, 1999 and Chaudhary *et al.*, 2001). Buse and Good (1996) observed the effect of temperature on the eggs of the winter moth, *O. brumata*. Williams and Liebhold (1995) discussed the influence of weather on the synchrony of gypsy moth outbreaks. In a recent article, Lyamtsev *et al.* (2000) reported the effect of climate and weather on the population dynamics of *L. dispar*.

General information on population dynamics is available from books and articles such as "Pest population and assessment of crop losses"(Atwal and Singh, 1990), "Ecology"(Krebs, 1978), "Biological control, thresholds, and Pest outbreaks"(Berryman, 1982), "Insect ecology"(Price, 1997),"Insects-An outline of entomology"(Gullan and Cranston, 1994), "Fundamentals of ecology" (Das, 1993), "Fundamentals of

Applied entomology"(Pfadt, 1985) and "Ecology of Insects" (Speight *et al.*, 1999).

3.5. Biology of major folivores:

There is no detailed information available on the biology and life cycle of *Gazalina chrysolopha* from Sikkim. However, an article "Observation on outbreak and biology of Oak defoliater, *Gazalina chrysolopha*" (Rehman and Chaudhry, 1992), from Pakistan gave some information on the insect's biology. Pangtey and Thakur (1986) in their article "Insect pest of large cardamom in Sikkim" reported about the outbreak of *G. chrysolopha* and gave an account of the wing expanse of adult moth. There is no report available on the biology of *Chrysomela chlorina.* Phaloura and Singh (1992) worked on the biology of *Aiolocaria hexaspilota*, a natural enemy of *C. chlorina*. In their article they mentioned that the larval stages of *C. chlorina* had synchrony with those of *A. hexaspilota.* Literature available on the biology of different chrysomelid beetles (Burkot and Benjamin, 1979; Jayant and Bali, 1993; Pandey and Tiwari, 2001) have been referred to support the findings of the present study.

In the present study, growth and development of major folivores in question, has been explained on the basis of the quality of food they consumed. Many articles are available on the role of food quality in regulating the growth and development of different insects. As early as 1966, in an article, Carne mentioned that less quantity of nitrogen (N) in

food, produced lighter females with lower fecundity in case of the chrysomelid *Paropsis atomaria*. Engelmann (1970) stated that egg production is a function of a multiplicity of factors (many of them species specific) such as temperature, metabolism, food constituents and quality. Later, Scriber and Slansky (1981) found that Nitrogen (N) concentration in tree foliage was lower than in herbaceous plants, which acted as the limiting factor in the development of insect defoliators feeding on trees. Ohmart *et al.* (1985) investigated the effect of food quality, especially Nitrogen (N), on chrysomelid larvae, *Paropsis atomaria*. Lindroth *et al.* (1997) in their work on gypsy moth showed that variation in temperature and dietary nitrogen affected its performance. Effects of food quality on the development and biology of other lepidopterans have been discussed by Mehra and Shah (1970), Devaiah *et al.* (1983), Muthukrishnan *et al.* (1993), Ray and Banerjee (1993), Sharma *et al.* (1994), Cambini and Magnoler (1999), and Kavita and Savirti (2001). Hemming and Lindroth (2000) observed the effect of food quality on performance of forest tent caterpillar. This was followed by similar work on winter moth by Ruuhola *et al.* (2001).

For morphometric and growth studies, some of the classical literatures are that of Dyar (1890), Majeed and Aziz (1979) and Sorensen and Thompson (1979), which has been referred to while determining the larval instars.

3.6. Nutritional Ecology of Major folivores:

Although there is no work done on the nutritional ecology of *Gazalina chrysolopha* and *Chrysomela chlorina,* well discussed article are available on post ingestive nutritional indices of lepidopterans (Scriber 1979 and Ruuhola *et al.*, 2001) that gave a holistic idea on nutritional ecology of tree-feeding caterpillars. There are articles available on food consumption and utilization by tree feeder, *Lymantria dispar* and winter moth, *O. brumata* (Barbosa and Greenblatt, 1979; Sheppard and Friedman, 1990; Kirsten and Topp, 1991; Lindroth *et al.*, 1997; Ruuhola *et al.*, 2001). Harrel *et al.* (1982) studied the food utilization efficiency of the chrysomelid, *Chrysomela scripta,* a congener of *C. chlorina,* which was useful while studying the nutritional ecology of *C. chlorina.*

In the present study, the food utilization efficiencies of *G. chrysolopha* and *C. chlorina* are discussed on the basis of the quality of food they consumed. Therefore, the nutritive quality of the leaves consumed by the major folivores was estimated. There are many reports stating that interaction between the different constituents, especially C and N, of food may determine the efficiencies of utilization of food, growth and reproduction (Muthukrishnan and Pandian, 1987) of the insects. However, certain inorganic elements such as K and P are also required at least in trace amounts for growth and reproduction of an insect (Dadd,1970). Therefore,

estimation of K and P was also done along with C and N as a supplementary study.

Some papers dealing with the effect of quality of food on food utilization efficiencies of the insects, are available from different authors such as Waldbauer (1968), Fenny (1968, 1976), Baker (1974), Duncan and Kelekowski (1975), Cates (1980), Fox and Macauley (1977), Slansky and Fenny (1977), Bhatt and Bhattacharya (1978), Barbosa and Greenblatt (1979), Larsson and Tenow (1979), Mattson (1980), Denno and Donnelly (1981), Sciber and Slansky (1981), Muthukrishnan and Pandian (1987), Ohmart *et al.*(1985), Farrar *et al.* (1989), Sheppard and Friedman (1990), Kirsten and Topp (1991), Panda and Khush (1995), Lindroth *et al.* (1997), Schoonhoven *et al.* (1998) and Ruuhola *et al.* (2001). Information on nutritional ecology relevant to some aspects of the present study has largely been obtained from some book articles by Muthukrishnan and Pandian (1987) in "Animal Energetics" and by Slansky and Rodriguez (1987) in "Nutritional Ecology Of Insects, Mites, Spider and related invertebrates". Other general informative material on nutritional ecology and insect-plant interaction is from the article "Insect nutrition: An adaptationist's perspective" (Slansky, 1982).

3.7. Ecological role of the major folivores in the large Cardamom agroforestry ecosystem:

This study was conducted to assess the contribution of faecal urine (in an outbreak, large quantity of frass dropped to the forest floor) to the soil fertility of the forest floor of *Alnus*-cardamom agroforestry.

Outbreaks of defoliating insects can have dramatic effects on forest ecosystem (Lovett *et al.* 2002). Several studies have indicated insect's frass or faecal pallet as contributors to soil fertility to the forest floor. Well documented articles by Mattson and Addy (1975), Lovett and Ruesink (1995) and Lovett *et al.*(2002) speaks for the contribution of decomposing frass of lepidopteran in terms of carbon and nitrogen mineralization and their incorporation into soil organic matter. Weis and May (1989) reported that in one year in Oak forest, insect frass contributed a fair amount of C, K, N and P to the soil enriching its fertility.

However, there is no information available on the contribution of feacal urine (frass) of the major folivores, *Gazalina chrysolopha* and *Chrysomela chlorina* to the *Alnus*- cardamom forest floor.

Negative impact of these major folivores, was assessed by calculating the quantum of leaf consumed (injured) by these insects (Pedigo, 1996). Similar assessment studies are available from other workers such as Simmonds (1949), Manjunatha *et al.* (1987), George and Ipe (2000) and Urban (2000).