6. Discussion
In the present study, evaluation of *A. mylitta* on different forest tree species in respect of the traits that contribute to its larval growth, reproductive potential and silk production efficiency were taken as primary research requisites as objectives in order to explore the feasibility of commercial rearing of *A. mylitta* in tropical forest areas of Uttarakhand. Study on the effects of host plants on the biology of an insect is important for understanding the host suitability under different environmental conditions (Xue et al., 2009). There have been a number of studies on the biological parameters of different economic insects on different host plants under different environmental conditions (Etman and Hooper 1979; Bae et al. 1997; Guan and Chen 1999; Ahmad et al. 2007), but *A. mylitta* has never been experimented in Uttarakhand (Bhatia and Yousuf, 2013d).

Most of the economic traits of silkworms are quantitative in nature and seasonal variables like temperature, relative humidity, rainfall, and photoperiod influence them greatly (Legay, 1958; Yokoyama, 1963). According to Allard and Bradshaw (1964), performance of an insect in a given environment itself indicates its superiority, so measuring the phenotypic and biometric manifestations of important economic characters of an insect on different host plants is inevitable. In present study, effect of rearing seasons, forestry host plants and their interactions was evaluated on forty economical traits of *A. mylitta* at New Forest, FRI Dehra Dun, in order to assess the adoptability and to find out the productivity level of tropical tasar silkworm in tropical forest conditions of Uttarakhand.

Data were analysed by applying reliable statistical methods for drawing the valid inferences. Rajlakshmi et al. (2000) reported that there exists a reciprocal relationship between different traits of silkworm. Multiple regression analysis was carried out on some of the important dependent variables of *A. mylitta* to assess the nature of association with their independent variables and to find out their strong predictor.

As forest based commercial rearing of *A. mylitta* may be a new forestry employment avenue for the people of Uttarakhand, so it was considered to assess the
major economic traits that influence silk yield of *A. mylitta*. Therefore, to find out the superiority of forestry host plants on different economic traits of *A. mylitta*, a common evaluation index (E.I.) method was applied as laid down by Mano *et al.* (1993). The use of E.I. in tropical tasar research sector is relatively new, and we have applied it for comparing the performance of *A. mylitta* on different forestry host plants, based on multiple traits E.I. analysis.

### 6.1 SUITABILITY OF DIFFERENT FORESTRY HOST PLANTS FOR THE DEVELOPMENT OF SILKWORM, *A. mylitta*

The role of host plant is an important factor in regulating insect population (Umbarihowar and Hastings, 2002) because variation in host plant quality affects the life history parameters of herbivores (Awmack and Leather, 2002). *A. mylitta* larvae shows selection of food plants, but selected plants may or may not support their development due to nutritive deficiency or presence of toxic substances (Nayak *et al.*, 2000; Hansda *et al.*, 2008; Ojha *et al.*, 2009). Forestry host plants differ greatly with their nutrient profile (Kohli *et al.*, 1969; Sinha and Jolly, 1971; Agarwal *et al.*, 1980; Sinha and Chaudhury, 1992; Puri, 1994) that has direct influence on the health, growth, and survival of *A. mylitta* (Sinha *et al.*, 1986). Better, the quality of leaves, greater are the possibilities for obtaining good cocoon crops.

Insect larvae of non feeding adult insects like *A. mylitta* are voracious feeders, hence their growth rate, developmental time, final body weight, survival and reproduction traits are influenced by the climate and food quality (Rath *et al.* 2006). Therefore, potential fitness of any insect is only possible when larvae obtain adequate amount of necessary nutrients in a suitable relative balance (Slansky and Scriber, 1985; Rath, 2005). The foliar constituents in a number of tasar food plants have been analysed for moisture, crude fibre, total minerals, reducing sugar, total sugar, starch, total nitrogen, and crude protein (Jolly *et al.*, 1979; NISCAIR, 1976; Puri, 1994; Sinha and Jolly, 1971).

Studies have also proven the significance of seasonal variations on biology and development of insects (Odum, 1983; Ouedraogo *et al.*, 1996). Temperature influences everything that an organism does (Clarke, 2003), humidity affects embryonic development (Tamiru *et al.*, 2012), and rainfall affects both (Getu, 2007).
Temperature, being major abiotic factor, regulates the body temperature of caterpillar that determines the rates of feeding, fecundity, and mortality (Casey, 1981; Wellington et al., 1999). The combined effects of temperature and relative humidity have also been reported on different biological and reproductive parameters of insects (Getu, 2007; Tamiru et al., 2012). Rainfall alters the functioning of microhabitat, which along with soil and other environmental factors affects foliage and water levels that consequently reflecting the distinct impact on performance of insect (Mattson and Haack, 1987).

Present study demonstrated that growth, development and cocoon productivity of *A. mylitta* differ significantly between rearing seasons, host plants and their interaction. Results of seven dependent variables assessed for suitability of different forestry host plants for the development of silkworm, *A. mylitta* are discussed below:

### 6.1.1 Larval weight

Relation between an insect and its food plants in different seasons depends on the efficiency of conversion of ingested food into body biomass. Therefore, it is essential to collect information on the effect of host plants on body mass of Lepidopteran larvae (Bhattacharya and Pant (1976). Analysis of results indicates that there was an increase of 19.35% in overall mean larval weight of *A. mylitta* from first rearing season (13.48 g) to second rearing season (16.09 g) and Tukey HSD test as shown in Table 5.3 evidence it. First rearing season was characterised by warm (26.25-29.25 °C) and wet (84.58-88.78 %.) weather conditions; however second rearing season was characterised by cool (17.28-26.15 °C temperature) and dry weather conditions (73.05-83.75% RH). Climatic variables such as temperature, humidity, rain, sunshine, and winds have enormous impact on ecological success of insects, because these abiotic factors fundamentally influence the host exploitation, growth, reproduction and dispersal. There are reports that forestry host plants reach to their maximum nutritional potentiality in second rearing season (Sinha and Jolly, 1971). Ponnuel el al., (1996) reported that biochemical constituents of oak (*Quercus serrata*) leaves vary with season.

Significant effect of forestry host plants was found on larval weight (P<0.05), which differ significantly on all the seven tested forestry host plants. Rearing results
indicated that *T. alata* provided the best nourishment to *A. mylitta* that influenced better larval growth in both the rearing seasons, followed by *T. tomentosa*, *T. arjuna* and *L. speciosa*. However, *L. tomentosa* fed larvae of *A. mylitta* showed minimum larval weight, followed by *T. chebula* and *T. bellirica*. In a comparative biochemical study of *T. tomentosa* and *T. alata*, Sinha et al., (2007a) found that non-hairy leaves of *T. alata* are better than hairy leaves of *T. tomentosa*. The moisture level, total carbohydrate, protein, amino acid and mineral contents were found higher in non-hairy leaves than the hairy leaves; however, total fibre content was found higher in hairy leaves of *T. tomentosa* and lower in non-hairy leaves of *T. alata*.

Results of the present study reflected that in the climatic conditions of New Forest, Dehra Dun, *A. mylitta* larvae grow well on *L. speciosa*, which is considered as a secondary host plant. Here, the performance of *A. mylitta* is almost equally well as that of the larvae fed on *T. arjuna* (Table 5.2). Results of present study are supported by the findings of Kumar et al. (2009), who reported higher larval weight of fifth instar larvae of *A. mylitta* on *L. speciosa* (31.18 g) than *T. arjuna* (29.76 g) during first crop rearing season in Ranchi, Jharkhand, whereas in second crop rearing, *T. arjuna* performed better than *L. speciosa*.

Less larval weight of *A. mylitta* on *L. tomentosa* and *T. chebula* might have been attributed to low availability of nutrients and higher contents of feeding deterrents; as the low biomass accumulation due to decreased food assimilation has been reported on less preferred host plants by insects (Shiva Kumar, 1995; Shiva Kumar et al., 1997).

### 6.1.2 Larval weight gain

Growth is defined as the change in size of individual organism or part of it, and development is change in form. Both phenomena are complex, their variables are interrelated, and it is difficult to quantify these variables; however, biomass gain is a useful parameter in ecological model to compare the superiority of different host plants (Gordon, 1999).

It was observed that during second rearing season, *A. mylitta* larvae gained significantly higher weight on all forestry host plants as compared to first rearing season (P<0.05). This phenomenon was in accordance with the established principle.
that environment influences the rate at which insects grow (Chapman, 1973). Dash et al. (1992) also reported the similar results for larval weight gain by A. mylitta in different rearing seasons on different food plants from Durgapur, Odisha. Reports are also available on the fact that nutritional quality of host plants leaves and their aging phenomenon due to seasonal variations appears to regulate growth and development of silkworm (Mansingh, 1972).

Superior performance of T. alata, T. tomentosa, T. arjuna and L. speciosa was found in respect of higher larval weight gain of A. mylitta over T. bellirica, T. chebula and L. tomentosa in both the rearing seasons (P<0.05). Absolute values for larval weight gain of A. mylitta were remained significantly at higher level in T. alata fed larvae over other food plants.

Variations in nutritional contents of the forestry host plants attributed to the variation in larval weight gain of A. mylitta and Table 5.8 evidenced. It is reported that T. alata contains higher sugar (8.0%) and higher starch (15.0%) than T. tomentosa, T. bellirica and T. chebula (NISCAIR, 1976). Higher nutritional availability in T. alata leaves might have influences more biomass accumulation by A. mylitta due to higher rate of food ingestion, food assimilation, and respiratory activity. Hiratsuka (1920) reported involvement of these factors in increasing the larval body substance in Bombyx mort.

Further, better larval weight gain of A. mylitta was found on T. arjuna as compared to L. speciosa, which may be due to less fibre in the leaves of T. arjuna (7.78 %) than L. speciosa (11.07%) as reported by Sinha and Jolly (1971) and Agrawal et al. (1980). There are reports that higher fibre contents in tasar food plants are detrimental for growth and development of A. mylitta (Kohli et al., 1969; Krishnaswami, 1978).

Negative effects of L. tomentosa and T. chebula, observed in the larval weight gain indicate that A. mylitta larvae were not able to completely compensate for variation in food quality as reported by Slansky (1982). Results of present study indicate that T. alata, T. tomentosa, T. arjuna and L. speciosa are the best-suited host plants that provide possibly all required nutritional components to A. mylitta larvae.
for better physiological performance under climatic conditions of Uttarakhand. Findings of Rath et al. (2000) supports the results of present findings.

**6.1.3 Relative growth rate**

Relative growth rate (RGR) indicates increase in body substance per unit of time with regard to the rate at which digested matter is available to the insect during experimental period (Bhattacharya and Pant, 1976). According to the logic of nutritional ecology, food consumption and utilization have adaptive significance for an insect. Slansky and Scriber (1985) outlined that in most of the cases, the combination of a certain growth rate and the attainment of a particular larval weight has a significant impact on biological success of an insect. Study of RGR is important because it reflects the time needed to attain final larval weight. If there is a slow growth rate below to ideal value, it reduces fitness due an extended larval period that increases vulnerability to predators and parasitoids (Price et al., 1980).

Results of present study indicated significant effect (P<0.05) of rearing seasons, host plants and their interaction on RGR of *A. mylitta*. Saradechandra and Joshi (1985), Reddy et al. (1989), Kumar et al. (1993) and Naik et al. (2010) had also found significant difference in growth index of eri silkworm with respect to different host plants, seasons, and their interaction.

Further, higher RGR of *A. mylitta* was found during first rearing season than second. Since larvae of first rearing season were exposed to higher temperature and low relative humidity regime, so their rate of feeding and corresponding physiological rate got increased that resulted into higher larval weight gain. Ojha et al. (2000) had also recorded similar trend of RGR of *A. mylitta*.

During the course of study, different RGR of *A. mylitta* larvae fed on different food plants have shown an interesting difference. *T. arjuna* provided fastest growth of *A. mylitta* during first rearing season; whereas, in second rearing season *T. alata* provided the best RGR. In both the rearing seasons, *L. tomentosa* fed larvae showed the lowest RGR followed by *T. chebula* and *T. bellirica*. The overall pattern of evaluation index (EI) values in respect of RGR followed the similar trend as that of their overall combined mean for first and second rearing seasons.
The maximum RGR of *A. mylitta* by feeding *T. alata* and *T. arjuna* leaves may have been attributed to the adapted feeding behaviour of the *A. mylitta* larvae to maximize its feeding rate at which the nutrition is absorbed from the gut that eventually led to maximum RGR. Reynolds *et al.* (1985) also observed same phenomenon in the case of tobacco hornworm, *Manduca sexta*.

*L. tomentosa* was taken as a host plant for the first time for *A. mylitta* and it was found that *A. mylitta* completed its life cycle on it, but its performance was lowest among all host plants of present study on all the studied parameters. Zhu *et al.* (2005) also found that *Spodoptera litura* larvae did not prefer feeding on banana leaves and had lower relative growth rate, but it had an extremely higher rate of efficiency of conversion of digested food. Similarly, *A. mylitta* did not like much to feed on *L. tomentosa* but completed its life cycle, which might be attributed to higher rate of efficiency of conversion of digested food.

### 6.1.4 Larval duration

In silkworm, shorter larval period is a desirable character that minimizes risk of losses from parasitoids, predators, and diseases. Most of the literature on dietetics of insects includes larval period as a major variable to determine the suitability of a diet. A good diet always supports larval development in shorter periods (Bhattacharya and Pant, 1976).

Current study indicates significant differences in larval duration between first rearing season and second rearing season. Literature suggests that temperature followed by humidity has a direct effect on growth and physiological activity of insect. Therefore, higher temperature regime during first rearing season accelerated the larval growth that shortens the larval duration of *A. mylitta*.

In first and second rearing seasons, *T. arjuna* and *T. alata* fed larvae registered shortest larval duration, respectively; whereas, *L. tomentosa* fed larvae showed highest larval duration in both rearing seasons, followed by *T. chebula* and *T. bellirica*. A variation of 30.24 days was observed in larval duration of *A. mylitta* larvae reared on different forestry host plants in the Uttarakhand. Such variation in larval duration might have occurred due to low nutrients level in the leaves of *L. tomentosa*, *T. chebula*, and *T. bellirica* (Jolly *et al.*, 1979; NISCAIR, 1976; Puri,
1994; Sinha and Jolly, 1971). Because, poor nutritional quality of host plants adversely affect the larval growth and development of herbivorous insects and need to feed more to reach next stage of development (Clancy and Price, 1987; Shreedhara et al., 1991). Benchmark and Jolly (1986) and Situmorang (2002) have reported that variations in the larval span caused variations in the cocoon parameters.

Further, prolongation of larval period in L. tomentosa and T. chebula fed larvae might become necessary to reach their intake and growth targets to attain functional optima as advocated by Raubenheimer and Simpson (1999). Kumar et al. (2009) had also reported that increase in larval duration of A. mylitta had advers effects on cocoon weight, and in such cases insects manages to accumulate required quantity of nutrients by extending the feeding period to maintain the critical level of growth (Slansky and Feeny, 1971).

Analysis of results also suggests that instar termination in A. mylitta fed on different host plants was not actually determined by attaining a fixed increment in the larval biomass. During experimental rearing, it was observed that some times starved larvae on L. tomentosa, a less preferred food plant by A. mylitta, eventually exuviated into the next stage, despite a very less relative growth rate or even loss of larval biomass.


Larval duration of A. mylitta is correlated with the profitability of tropical tasar Seri-business, as the cost of labour engagement depends on larval duration. This study indicates that for Uttarakhand, T. alata, T. tomentosa, T. arjuna and L. speciosa are the best-suited host plants to realise maximum profitability from forest based commercial rearing of A. mylitta.
6.1.5 Weight of silk gland

Silk gland is an important organ of *A. mylitta* that produces liquid silk, which is the source of cocoon fibre. Silk glands grow very fast from the time of hatching to final stage of mature larva. Growth of silk gland involves increase in size of each cell, but not the increase in its number (Aruga, 1994).

It was found that seasons, host plants and their interaction affected the weight of silk gland significantly (P<0.05). Further, in second rearing season, there was an increasing trend in the weight of silk gland on all the forestry host plants. The seasonal variations for this trait are in conformity with the findings of Yokoyama (1963), who demonstrated effect of season on development of silk gland in *B. mori*.

It was further found that *T. alata*, followed by *T. tomentosa*, *T. arjuna* and *L. speciosa* yielded silk gland of higher weight; whereas, *L. tomentosa* fed larvae showed the lower weight of silk gland, followed by *T. chebula* and *T. bellirica*. Result of evaluation index analysis also reflected the same trend. Nutritional profile of *T. alata*, *T. tomentosa*, *T. arjuna* and *L. speciosa* is reported to be superior than *T. chebula*, *T. bellirica* and *L. tomentosa* (Kohli et al., 1969; Sinha and Jolly, 1971; Jolly et al., 1979; Agarwal et al., 1980) that might have influenced the weight of silk gland of *A. mylitta* on these forestry host plants. Lower nutritional contents and poor palatability of the leaves of *L. tomentosa* and *T. chebula* caused lower silk gland weight in the matured larvae of *A. mylitta*. Findings of Banagade and Tembhare (2002) support this assertion, who concluded that starvation caused significant reduction in synthesis of silk gland protein. Effect of various food plants on concentration of amino acid in the haemolymph of *A. mylitta* is also reported (Hsiao, 1985), to affect weight of silk gland in matured larvae of *A. mylitta* (Lokesh et al., 2012).

Rajesh Kumar and Elangovan (2010) had also found significant variations in the silk gland weight of eri silkworm reared on different food plants. Results of present study are also supported by the findings of Lokesh et al., (2012), who studied variability in silk gland of three ecoraces of *A. mylitta* viz., Daba, Sukinda, and Sarihan by rearing on *T. arjuna* and found that Daba ecorace showed highest weight of silk gland.
Results of multiple regression analysis indicated that the larval weight gain had significant positive regression on mean weight of silk gland. It indicates that with increase in larval weight gain, a simultaneous increase can be expected in the weight of silk gland. Regression equation indicates that larval weight gain is a strong predictor for corresponding silk gland weight of *A. mylitta*. Secondly, larval duration showed significant negative regression on mean weight of silk gland. This indicates that with reduction in larval duration, weight of silk gland may also increase. It proves that less larval duration is a desirable feature for *A. mylitta* to have better silk production efficiency and the host plant that supports faster larval growth is superior.

### 6.1.6 Cocoon yield

Cocoon yield in *A. mylitta* is a complex character that depends on interaction of various contributing traits (Sinha *et al.*, 1995). Cocoon crops of *A. mylitta* depend on developmental vigour of silkworm and rearing season and quality of the host plants (Venugopal and Krishnaswami, 1987). Results of the present study also indicated that cocoon yield of *A. mylitta* differs significantly between rearing seasons and host plants (P<0.05).

In present study, higher cocoon yield was found in first rearing season than the second one, which confirms that seasonal variations play a major role in the growth and development of *A. mylitta* larvae and weight of silk gland that contribute to cocoon yield (Ueda *et al.*, 1969; Takeshita *et al.*, 1975; Mathur and Mathur, 1996). Further, in second rearing season, prolonged larval period due to low temperature (Tamiru *et al.*, 2012) increases caterpillar’s exposure to natural enemies (Isenhour *et al.*, 1987), because larval period is inversely related to temperature and relative humidity (Tamiru *et al.*, 2012).

In present study, food plants showed significant influence on cocoon yield of *A. mylitta*. It is found that *T. alata* fed larvae showed highest cocoon yield, followed by *T. tomentosa*, *T. arjuna* and *L. speciosa* fed larvae. Whereas, *L. tomentosa* fed larvae showed the lowest cocoon yield, followed by *T. chebula*. It was also found that cocoon yield of *T. tomentosa* and *T. arjuna* fed larvae did not differ significantly with each other. Our results are showing the conformity with the findings of Deka and Kumari (2013), who had assessed the effect of *T. tomentosa*, *T. arjuna*, *T. bellirica*, *T.*
chebula, L. speciosa and L. parviflora on rearing performance and cocoon characteristics of A. mylitta in the agro-climatic conditions of Ranchi, Jharkhand and reported comparable performance of T. tomentosa and T. arjuna in cocoon productivity.

The success of an insect depends significantly upon an optimal diet in both quantity and quality (Hassell and Southwood, 1978), which provides energy, nutrients, and water to carry out life's activities (Slansky, 1993). Carbohydrates, proteins, and lipids are the main sources of energy at the time of larval-larval, larval-pupal, pupal-adult transformation (Krishnaswami, 1978; Thangamani and Vivekanandanan, 1984). Availability of these nutritional components has been reported in T. alata, T. tomentosa, T arjuna and L. speciosa having higher than T. bellirica, T. chebula and L. tomentosa (Agrawal et al., 1980; Sinha and Jolly, 1971; NISCAIR, 1976).

Reports are available on moisture contents of the host plant leaves, which has a positive correlation with cocoon productivity of A. mylitta (Krishnaswami, 1978; Thangamani and Vivekanandanan, 1984). High moisture content in the leaves has favourable effects on the palatability and assimilability of nutrients (Parpiev, 1968). Deka and Kumari (2013) found higher leaf moisture content of 72.07% in T. tomentosa, followed by L. speciosa (71.21%) and T. arjuna (70.36%) and recorded cocoon productivity of 86, 80 and 82 cocoons/DFL, respectively. These results support the present findings. Further, some workers (Stride and Stratman, 1962; David and Gardiner, 1966; Jemmy et al., 1968; Fraenkel, 1969) have produced experimental evidences in support of the contention that insect becomes “conditioned” to a particular host plant, because food first eaten by a phytophagous insect becomes its subsequent feeding behaviour. In our experimental rearing also, this fact stands true for the larvae of A. mylitta, which adopted L. tomentosa host plants by the first time and completed its life cycle.

Our results confirmed that for achieving best cocoons productivity of A. mylitta in tropical forest areas of Uttarakhand, T. alata is the best-suited food plant, followed by T. arjuna, T. tomentosa, and L. speciosa.
6.1.7 Effective rate of rearing

Effective rate of rearing (ERR) indicates the success rate of silkworm rearing based on larval survivability from brushing until completion of cocoon formation. Our study reveals that ERR of *A. mylitta* differ significantly between rearing seasons, among host plants (P<0.05); but their interactions were found insignificant (P>0.05). Siddiqui *et al.* (1989), Rath (2000), Dash *et al.* (1994) and Reddy *et al.* (2012) has also found significant difference in ERR of *A. mylitta* reared on different forestry host plans.

ERR was found higher during first rearing season as compared to the second rearing season. Devaiah and Dayashankar (1982) have also reported that the ERR largely depends on type of the host plants along with the rearing season. It was further found that in both the rearing season, *T. alata* fed silkworm larvae showed highest EER, followed by *T. tomentosa*, *T. arjuna* and *L. speciosa*. However, *L. tomentosa* fed larvae exhibited lowest ERR, followed by *T. chebula*. Result also indicates that the overall ERR of *T. arjuna* and *T. tomentosa* fed larvae did not differ significantly. All the tested forestry host plants, differing in their nutritional contents, affected the growth and development of *A. mylitta* and ultimately ERR differed significantly between host plants in both the rearing seasons.

Our results are in close conformity with the findings of Srivastava *et al.*, (1994), who used five forestry host plants for rearing of *A. mylitta* under the climatic conditions of Ranchi, and found that *T. tomentosa* excels in ERR, followed by *T. arjuna*, *Ziziphus jujuba*, *L. parviflora* and *S. robusta*. Further, results of Ahsan and Griyaghay (1973) had also demonstrated higher ERR of *A. mylitta* on *T. arjuna* and *T. tomentosa*. They attributed reasons for high percentage of mortality in *Z. jujube* and *S. robusta* fed larvae to the bad quality of leaves, which were over mature with less moisture content having high percentage of fibre contents.

Extended larval span of *A. mylitta* by feeding the leaves of *L. tomentosa* *T. chebula* and *T. bellirica* as compared to *T. alata*, *T. tomentosa* and *T. arjuna* contributed negatively in terms of low ERR and cocoon yield with the probability of longer exposure to environmental vagaries, diseases, pests and predators.

Our results indicates that for achieving higher benefit from forest based rearing of *A. mylitta* in Uttarakhand, *T. alata*, *T. tomentosa*, *T. arjuna* and *L. speciosa*
are the most suitable forestry host plants. It is important to mention that the performance of *A. mylitta* rearing on *L. speciosa*, which is considered as a secondary host plant, was found very close to that of *T. arjuna* fed larvae, which is a primary host plant for *A. mylitta*. Therefore, for commercial rearing of *A. mylitta* in Uttarakhand, plantation of *L. speciosa* as a primary host plant can be utilised.

### 6.2 Reproductive Potential of *A. mylitta* Reared on Different Forestry Host Plants

Reproduction potential of an insect closely relates with the nutritional factors of the host plant (Rath, 2000). Adult emergence, adult weight, fecundity and fertility of *A. mylitta* are influenced by host plant species (Rath *et al.*, 1997) and environmental conditions (Zhu *et al.*, 2000; Chen *et al.*, 2002). Results of various reproductive variables under the present study are discussed below:

#### 6.2.1 Emergence Percentage of Male and Female Moths

It was found that emergence percentage of ♂ and ♀ moths differ significantly between rearing seasons, among host plants and their interactions (P<0.05). Higher moth emergence was observed during second grainage season as compared to first grainage season. Optimal temperature and relative humidity regime might have stimulated the reproductive physiology of the diapausing pupae. Mishra *et al.* (1997) have also recorded higher moth emergence in second grainage season. Further, Nayak *et al.* (1993) had found positive correlation between temperature and relative humidity and percent male and female emergence of *A. mylitta*. Jolly *et al.* (1974) have also demonstrated significant effect of environmental variables on moth emergence and coupling percentage of *A. mylitta*. On second hand, seed cocoons utilised during first grainage season were subjected to preservation period of more than six months that inflicted higher preservation losses and therefore, moth emergence percentage of both the sexes were adversely affected.

Our results indicated that cocoons of *T. alata* fed larvae recorded highest emergence percentage, followed by the cocoons of *T. arjuna*, *T. tomentosa* and *T. bellirica* fed larvae. This is supported the findings of Nayak *et al.* (1993) and Mishra *et al.* (1997) who also found significant difference in emergence percentage of ♂ and ♀ moths of *A. mylitta*, reared on different host plants during different rearing seasons.
Furthe, Rath (2000) had also reported significantly higher adult emergence of *A. mylitta* from the cocoons of *T. tomentosa* and *T. arjuna* fed larvae than other host plants species.

### 6.2.2 Copulation percentage

Copulation percentage is an important reproductive variable of *A. mylitta* that influences production of disease free layings (seed), as mating and oviposition are two important behavioural aspects of insect reproduction.

It has been found during present study that copulation percentage differ significantly between rearing seasons and host plants (P<0.05); however, their interactions were found insignificant (P<0.05). Unlike, moth emergence percentage, copulation percentage was recorded higher in first grainage season, as compared to second grainage season, which might have been attributed to the optimal temperature and relative humidity regime. The lower coupling percentage recorded during second grainage might be the result of lower temperatures and lower relative humidity during winter.

There are reports revealing that life history features such as moth emergence, coupling percentage, fecundity, and percentage of hatching of *A. mylitta* are variable between seasons (Jolly *et al.*, 1974). Nayak and Dash (1989) had demonstrated the influence of weather variables on reproduction in *A. mylitta*. Nayak *et al.* (1993) had also found significant difference between coupling percentage of *A. mylitta* during different rearing seasons. They had found a positive correlation between weather variables and copulation percentage of *A. mylitta*. Furthermore, results of the present investigation also corroborate the findings of Mishra *et al.* (1997), who reported that the rearing seasons and forestry host plants of *A. mylitta* have significant effect on coupling percentage. However, unlike findings of the present study, they had recorded maximum coupling percentage during second grainage season, when larvae were reared on *T. tomentosa*; however, it was found lowest on *S. robusta* during winter season.

Tukey HSD test for the effect of host plants on copulation percentage suggests that moths emerged from the cocoons of *T. arjuna, T. tomentosa, L. speciosa* and *T. alata* fed larvae did not differ significantly and formed a homogeneous group.
However, Reddy et al. (2010) found significantly higher copulation percentage of *A. mylitta* in the moths of *T. tomentosa* fed larvae than *L. parviflora* fed larvae.

Results of multiple regression analysis show that emergence percentage of ♀ moth has significant positive regression weight on mean copulation percentage of *A. mylitta*, which indicates that with increase in ♀ moth emergence, copulation percentage is also expected to improve; this supports that emergence percentage of ♀ moths is a strong predictor for mean copulation percentage of *A. mylitta*.

Findings of the present study confirm that for the best copulation percentage of *A. mylitta* in climatic conditions of Uttarakhand, four forest tree species viz., *T. alata, L. speciosa, T. tomentosa* and *T. arjuna* in their order of merit, are the best suitable host plants.

### 6.2.3 Weight of male and female moths

It was found during the present study that weight of ♂ moths was always lower than ♀ moths in all the replicates during the both seasons. It is reported that functional roles of male and female differs in the adult stage, which is also reflected due to differences in the consumption and utilization of food by male and female larvae. Females tend to be heavier than males (Scriber and Slansky, 1981), indicating greater nutrient accumulation, associated with their role as egg-producers that generally results from increased food consumption by female larvae because of a longer duration of the larval stage than their male counterpart (Slansky and Scriber, 1985).

In present study, weight of the ♂ and ♀ moths differed significantly between rearing seasons, among host plants and their interactions (P<0.05). Further, weight of ♂ and ♀ moths was significantly higher during first grainage season. In both the grainage seasons, highest mean weight of ♂ and ♀ moths was recorded by the moths of *T. alata* fed larvae, followed by the moths of *T. tomentosa, L. speciosa* and *T. arjuna* fed larvae; whereas, moths of both sexes, whose larvae fed on *L. tomentosa* and *T. chebula* showed minimum weights. This might be due to variations in food quality that had a positive or negative impact on adult performance (Scriber and Slansky, 1981; Slansky and Scriber, 1982).
There are also reports that size of the moths of *A. mylitta* varies with nutritional contents of different food plants at different altitudes (Miller, 1991; Nayak, 1997). Rath (1998) had also found significantly higher weight of ♀ moths whose larvae were reared on *T. tomentosa* than that of *T. arjuna*; but, female weight did not differ significantly. Farrell, (1973; 1975) reported that host plant influences the weight of female that affects fecundity of individual female. Female of *A. mylitta* with higher weight improves silkworm fecundity (Yadav et al., 2001).

### 6.2.4 Mean longevity of male and female moths

The longevity of ♂ and ♀ moths influences grainage performance of *A. mylitta* (Rath et al., 1997). During the present study the mean longevity of the ♂ and ♀ moths differ significantly between rearing seasons, among host plants and their interactions (P<0.05). Further, mean longevity of ♂ and ♀ moths increased significantly during first grainage season on all the forestry host plants. Adult longevity became shorter as temperature increases (Bae and Park 1999).

Further, it has been observed that during both the grainage seasons, highest mean longevity of ♂ and ♀ moths were recorded by the moths of *T. alata*, *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae; however, lowest value was shown by the moths of *L. tomentosa* and *T. bellirica* fed larvae. These findings reveals that due to change in food quality, parameters on quantitative nutrition combinedly influence adult characters and reproductive fitness of *A. mylitta*, which are in accordance with the findings of Sinha et al. (2000); Sperber and Slansky (1981); Sperber and Feeny (1979); Slansky and Sperber (1982); Periasamy and Radhakrishnan (1985). Reddy et al. (1989) and Naik et al. (2010) had also recorded significant variations with regard to longevity of male and female moths of *Samia cynthia ricini* reared on different host plants, these variations were due to chemical composition of leaves that varies from season to season and from locality to locality.

The leaves of *T. tomentosa* are hairy and *T. alata* are non-hairy. It is clear that because of higher nutrition in the leaves of *T. alata* (Sinha et al., 2007a), the grainage performance was quite better on *T. alata* than *T. tomentosa*. Selinal (1985) revealed that food quality is responsible for attaining physiological potential of an insect that corroborates present findings. Further, present study is indicating that higher value of
E.I. for mean longevity of ♂ and ♀ moths on *L. speciosa* than *T. arjuna* reflect superiority of *L. speciosa* over *T. arjuna*.

Further, it is divulged that ♂ moths lived longer than ♀ moths. Similarly, Ravishankar *et al.* (2000) had also observed that ♂ moths of eri silkworm lived longer (9.60 days) than ♀ moths (7.35 days). Xue *et al.* (2009) had also reported that ♂ adults of *S. litura* lived longer than females, but differed on different host plants.

### 6.2.5 Average fecundity and coefficient of egg laying

Fecundity of mother moth is a crucial element in reproductive behaviour of *A. mylitta*. In present study, mean fecundity and mean coefficient of egg laying differ significantly between rearing seasons, host plants and their interactions (*P*<0.05). Nayak *et al.* (1993) and Mishra *et al.* (1997) had also found significant difference in fecundity of *A. mylitta* during different seasons.

During present study, higher fecundity in all the mother moths was recorded during first grainage season; however, mean coefficient of egg laying did not follow any definite trend. Deka *et al.* (2011) had also reported higher fecundity of *A. mylitta* in first grainage season.

Present study also reveals the highest mean fecundity and coefficient of egg laying in the mother moths of *T. alata* fed larvae, followed by *L. speciosa*, *T. tomentosa*, and *T. arjuna* fed larvae; whereas, lowest fecundity was realised from the mother moths of *L. tomentosa* and *T. chebula* fed larvae. Host plant quality is the key determinant factor for the fecundity of herbivorous insects (Awmack and Leather, 2002). Rath (2000) had also demonstrated significant differences in fecundity and coefficient of egg laying of *A. mylitta* reared on different forestry host plants. Chaudhuri (2003) and Radjabi *et al.* (2009) reported that larval feeding and quality of food plants have significant impact on genital development, fecundity, and egg fertility in the mother moths of *A. mylitta*.

It can be concluded that reduced fecundity in *L. tomentosa* and *T. chebula* might be due to lack of proper nutrition or proportionally higher diversion of assimilated food for maintenance of other life activities instead of production of eggs. There are many reports that food deprivation during larval stage had a negative impact on the fecundity in many insects including sericigenous species (McGinnis

Present results established that for Uttarakhand, *L. speciosa* is a potential primary host plant to have better fecundity and coefficient of egg laying of *A. mylitta* in comparison to *T. tomentosa* and *T. arjuna*. This finding is very significant to make progressive planning to introduce *L. speciosa* based commercial rearing of *A. mylitta* in tropical forest areas of Uttarakhand.

### 6.2.6 Incubation period and hatching percentage

Time between egg laying and emergence of the first instar larva measures the development rate of insect eggs (Tear et al. 1988). Hatching percentage is an important variable that indicates vitality and healthiness of the eggs that determines initial population of larvae at the time of brushing. In forestry tasar sector, less incubation period and higher hatching percentage is prefered.

In current study, it has been recorded that mean incubation period and hatching percentage of *A. mylitta* eggs differ significantly between rearing seasons and host plants (P<0.05). Hatching percentage was higher in first grainage season, as the temperature and relative humidity played a vital role in incubation of silkworm egg. Nayak et al. (1993) had also found significant difference in hatching percentage of *A. mylitta* during different rearing seasons.

Presently, highest mean incubation period was recorded for the eggs, whose mother moths were developed by *T. chebula*, followed by *T. bellirica* and *L. tomentosa* fed larvae; whereas, it was found lowest in the replicates of *L. speciosa*, followed by *T. tomentosa*, and *T. alata* in second rearing season. This difference in incubation period might have been attributed due to differences in allocation of assimilated nutrients by the larvae fed on different host plants. There are reports revealing that incubation period of silkworm eggs vary with the variations in host plant species (Jolly et al., 1979; Sarkar, 1980; Reddy et al., 1989; Naik et al., 2010).

Further, highest mean hatching percentage of the eggs were shown by the mother moths that were developed by *T. alata* followed by *T. arjuna* fed larvae; whereas, it was minimum in the eggs whose mother moths were developed by *L. tomentosa* and *T. chebula* fed larvae. Reddy et al. (2010) had also reported that
forestry host plants affects fertility percentage of *A. mylitta*. Present findings indicating that for having better hatching percentage of the eggs of *A. mylitta*, four forestry host plants viz., T. alata, T. arjuna, T. tomentosa and L. speciosa, in their order of merit, are the best suitable.

6.2.7 Weight of hatched larvae

It has been found that weight of the hatched larvae differed significantly between rearing seasons, host plants and their interactions (*P*<0.05). Lack of pertinent literature pervades critical comparison on effect of forestry host plants on weight of the hatched out larvae of *A. mylitta*. However, it can be presumed that feeding behaviour and varying nutritional contents in the leaves of tested forestry host plants along with seasonal variations might have corroborated to variations in weight of the hatched larvae of *A. mylitta*.

Results of present findings concluded that for having higher weight of hatched out larvae of *A. mylitta* in the climatic conditions of Uttarakhand and its rearing should be carried out on T. alata, T. arjuna and T. tomentosa host plants.

6.3 ECONOMIC TRAITS OF COCOONS AND SILK PRODUCTION EFFICIENCY OF *A. mylitta* REARED ON DIFFERENT FOREST TREE SPECIES

Host plants and rearing seasons influence the economic traits of cocoons and silk production efficiency in silkworms (Ueda et al., 1971; Hough and Pimental, 1978; Pillai et al., 1987; Lindroth and Hemming, 1990). Cocoons of *A. mylitta* show considerable variations in their colour, size, shape, pupal weight, shell weight, and silk output etc. (Jolly et al., 1974, 1979) and such variations are governed by silkworm race, climatic conditions of the rearing site, food plants, altitude etc. (Nayak and Guru, 1998 a & b). Results on the effect of forestry host plants and rearing seasons on the economic traits of cocoons and silk production efficiency of *A. mylitta* in Uttarakhand are discussed as under:

6.3.1 Peduncle length of male and female cocoons

Silk producing insects present a great deal of variation in the colour and morphological characters of cocoons and pupae fed on different host plants (Lefroy,
Variations in the peduncle length of ♂ and ♀ cocoons are significant between rearing seasons, host plants and their interactions (P>0.05). According to Panda (1972), peduncle character of *A. paphia* cocoons is an important feature for accurate identification of their variety (Bogai or Nadia).

Present results indicate that rearing season influence length of peduncle in both the sexes. In second season, it was higher on all the forestry host plants except *T. alata*. Host plants have also showed significant effect on peduncle length in both the sexes, as cocoons generated on *T. alata, T. tomentosa* and *T. arjuna* have shown higher peduncle length as compared to *L. speciosa, T. bellirica, T. chebula*, and *L. tomentosa*. Such fluctuations in peduncle length might have been attributed due to variations in larval weight gain owing to variations in availability of foliar nutrients in the leaves of tested host plants.

Further, irrespective of rearing seasons and host plants, it has been observed higher peduncle length in ♀ cocoons as compared to ♂ cocoons. Nayak and Guru (1998a) and Srivastava et al. (2002) had also found higher peduncle length in ♀ cocoons as compared to ♂ cocoons in Daba ecorace of *A. mylitta* under Ranchi conditions.

### 6.3.2 Length and breadth of male and female cocoons

Experimental data of the present study clearly revealed that length and breadth of ♂ and ♀ cocoons differ significantly between rearing seasons, among host plants and their interactions (P>0.05). In second rearing season, *A. mylitta* produced higher size of cocoons on all the forestry host plants. Further, *T. alata, T. tomentosa* and *T. arjuna* fed larvae produced bigger size of cocoons in both the rearing seasons as compared to *L. tomentosa* and *T. chebula*. Similar variations were also observed by Srivastava et al. (2002) and Nayak and Guru (1998a).

Jindra and Sehnal (1989) advocated that due to insufficient nutritive quality of host plant, production of silk protein decreased that led to formation of smaller cocoons in *Gallerea mellonella*. Therefore, it can be inferred that similar phenomenon may have prevailed in case of *L. tomentosa* and *T. chebula* fed larvae of *A. mylitta* that resulted into formation of smaller size of cocoons as compared to *T. alata T. tomentosa* and *T. arjuna* fed larvae.
Further, in both the rearing seasons, length and breadth of female cocoons was found higher than male cocoons on all the forestry host plants. Panda (1972) had also made similar observations in case of *A. paphia*.

Results of multiple regression analysis indicate that the mean breadth of cocoons in both the sexes had significant positive regression weight on mean shell ratio of *A. mylitta*. This suggests that with increase in cocoon breadth, shell ratio will also increase. Therefore, cocoon breadth is strong predictors for shell ratio in the cocoons of *A. mylitta*. Panda (1972) has also found positive correlation between length and breadth of *A. paphia* cocoons with cocoons weight.

### 6.3.3 Length and breadth ratio of male and female cocoons

Length and breadth ratio (LB ratio) of a cocoon indicates its shape. If LB ratio is one, it entails that cocoon is perfectly spherical. Further, Somashekar (2003) reported that oval shaped cocoons facilitate reeling process. It summarises that lower values of LB ratio in the cocoons of *A. mylitta* is always preferable.

It was found that rearing seasons does not affect LB ratio of ♂ cocoons (P<0.05); whereas, it differed significantly between host plants and their interactions (P>0.05). However, in ♀ cocoons LB ratio differed significantly between rearing seasons, among host plants and their interactions (P>0.05).

It is also noted that during second rearing season; mean LB ratio of ♀ cocoons was lower on all the forestry host plants, which indicates that cocoons produced in second rearing season are superior to the cocoons of first rearing season. Further, Lower LB ratio of the cocoons of *T. alata, T. tomentosa* and *T. arjuna* fed larvae indicated their superiority over *L. tomentosa* and *T. chebula* fed larvae.

Results of multiple regression analysis showed that mean LB ratio of ♂ cocoons had significant positive regression weight on its mean shell ratio. This suggests that with increase in values of mean LB ratio, the mean shell ratio will also increase. Lack of pertinent literature pervades further comparison on the effect of rearing season and forestry host plants on LB ratio of the cocoons of *A. mylitta*.
6.3.4 Weight of male and female cocoons

Cocoon weight is an important commercial character that determines selling prices of cocoons. Cocoon weight indicates the approximate quantity of raw silk that can be reeled from it. Host plants quality and rearing seasons influences the cocoon weight of *A. mylitta*, and a higher value of this trait is always desirable that indicates the healthiness and compactness of the cocoons (Rath, 2000).

Results of present study indicated that mean weight of ♂ and ♀ cocoons differed significantly between rearing seasons, among host plants and their interactions (P<0.05). Cocoons produced during second rearing season showed higher weight on all the forestry host plants. Sengupta *et al.* (2002) has also recorded significantly higher cocoon weight in Daba ecorace of *A. mylitta* in second rearing season than first rearing season at Ranchi in Jharkhand state.

It has been found that weight of ♀ cocoons is comparatively higher than ♂ cocoons in both the rearing seasons on all the forestry host plants. Since, ♀ larvae consume 16% more, digests 28% more (Rath, 2010a) and gain 12% higher larval weight (Rath *et al.*, 2006); therefore, average weight of ♀ cocoons is found always higher than ♂ cocoons. There are reports that higher cocoon weight has direct positive correlation with pupal weight and silk yield (Gowda *et al.* 1988 and Govindan *et al.* 1990).

Further it has been observed that in both the rearing seasons, *T. alata* fed larvae produced maximum cocoon weight, followed by *T. tomentosa*, *T. arjuna* and *L. speciosa* fed larvae; whereas, minimum cocoon weight was shown by *L. tomentosa* and *T. chebula* fed larvae. These results corroborates the findings of Kumar *et al.* (2006), Rath (2000) and Kumar *et al.* (2011), who also reported that *T. tomentosa* fed larvae of *A. mylitta* produces higher cocoon weight than *T. arjuna*, *L. speciosa*, *T. chebula*, *A. latifolia* and *Z. jujuba* fed larvae (in order of merit). However, present findings differs with the findings of Deka and Kumari (2013), who reported maximum cocoon weight on *T. arjuna* followed by *T. tomentosa*, *T. bellirica*, *L. speciosa* and *T. chebula*. Further, Reddy *et al.* (2012) had found non-significant difference (P>0.05) in single cocoon weight of *A. mylitta* reared on *T. tomentosa* and *L. parviflora* food plants under the climatic conditions of Ranchi, Jharkhand.
It is reported that leaf nutrition of tasar food plant enhances the growth of *A. mylitta* larvae that has direct positive correlation with cocoons and shell weight along with silk filament length in the produced cocoons (Dash *et al.*, 1992; Yadav and Mahobia, 2010). Therefore, it can be inferred that higher nutritive values in the leaves of *T. alata, T. tomentosa, T. arjuna and L. speciosa* (Jolly *et al.*, 1979; NISCAIR, 1976; Puri, 1994; Sinha and Jolly, 1971; Sinha and Jolly, 1971) and better rate of their intake, digestion and assimilation (Krishnaswami *et al.*, 1970; Ray *et al.*, 1998; Rahman *et al.*, 2004, Saikia *et al.*, 2004) were the prime reason for improved cocoon weight of *A. mylitta* on these host plants. (Krishnaswami *et al.*, (1971a) and Prasad *et al.* (2004) have also reported that the rearing performance of *A. mylitta* larvae strongly correlate with water and nitrogen content of the leaves. Significant effect of rearing season and food plants on cocoon weight of eri silkworm (Biswas and Dash, 2001; Hajarika *et al.*, 2003; Srivastava *et al.*, 1994; Rajesh Kumar and Elangovan, 2010) and muga silkworm (Barah *et al.*, 1988) have been also reported.

Results of multiple regression analysis indicate that mean weight of ♂ and ♀ cocoons had significant positive regression weight on mean shell ratio of *A. mylitta*. This finding suggests that with increase in mean cocoon weight, the mean shell ratio will also increase. Panda (1972) had also conducted correlation studied on cocoon characters of *A. paphia* and found highly significant positive correlation between cocoon weight and their shell weight and concluded that heavier cocoons contains higher shell weight. However, cocoon weight and shell weight tend to show negative correlation with peduncle length.

### 6.3.5 Shell weight of male and female cocoons

More important than the weight of the whole cocoon is the weight of silk shell that provides silk for reeling. Hence, heavier the weight of shell, greater would be the silk yield from it. Cocoon shell weight and its thickness uniformity are important for commercial cocoon characters in raw silk reeling that relates economic margin of raw silk production. Present findings reveal that mean shell weight of ♂ and ♀ cocoons differ significantly between rearing seasons, among host plants and their interactions (P<0.05). Siddiqui *et al.* (2006) have also reported that type of the food plants and environment of silkworm rearing influences cocoon shell weight and cocoon shell ratio in *A. mylitta*. 

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Further, it was found that cocoons produced in second rearing season showed higher shell weight in both the sexes on all the forestry host plants, which might be resulted due to favourable temperature and humidity regime for proper growth and development of *A. mylitta* larvae and adequate nourishment from the forestry host plants in second rearing season.

Further, it has been observed that *T. alata* produced cocoons registered higher shell weight, followed *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae. Whereas, the minimum cocoon shell weight was recorded in the cocoons of *L. tomentosa*, followed by *T. chebula* and *T. bellirica* fed larvae. Kumar et al. (2006) had carried out bioassay studies of *A. mylitta* on different accessions of *Terminalia* and *Lagerstroemia* spp. in Ranchi, Jharkhand and found maximum shell weight on *T. arjuna*, followed by *T. tomentosa*, *L. speciosa* and *T. chebula*, respectively. Their results were a bit different from the present findings. The quality of tasar food plant in terms of nutrition can influence weight of cocoon and silk ratio that influences crop economics (Muthukrishnan and Pandian, 1987; Reddy, et al., 2010).

Further, proteins are the ubiquitous nitrogenous compounds in the tasar food plants that involves practically in all the structures and functions of the cell (Sinha et al., 2007a). Machii and Katagiri (1991) reported that mulberry varieties containing higher contents of protein in their leaves have shown higher production efficiency of cocoon shell. Crude protein content is reported to be higher in *T. alata*, *T. tomentosa* *L. speciosa* and *T. arjuna* (Sinha and Jolly, 1971 and Agrawal et al., 1980), which might have contributed to heavier shell weight of the cocoons. Moreover, Bose et al., (1995) has also reported that succulent leaves with less fibre and higher mineral contents stimulate the metabolic activities in silkworm that results in quantitative improvement of cocoon and silk. They found *T. tomentosa* and *T. arjuna* are superior to *Shorea robusta* in this respect, because they contain higher percentage of total minerals (8.08% and 6.82% respectively) and lower amount of crude fibre (16.09% and 12.82%), respectively.

Results of present study also indicated that mean shell weight of ♂ and ♀ cocoons on *T. arjuna* and *L. speciosa* did not differ significantly and formed one homogeneous group. This pattern of cocoon shell weight of *A. mylitta* on *L. speciosa* may be a boon for forest dependent people in Uttarakhand, because climatic
conditions of Uttarakhand are more conducive for better growth and development of *L. speciosa*.

*Secondly, L. speciosa* flourish very well here and produces more quality foliage and many time more larger size of lamina than *T. arjuna*. Hence more leaves area is available for silkworm feeding that reduces burden of transfer during late age rearing, which also reduces labour wage.

*Third, L. speciosa* is not normally preferred for grazing by browsing animals. *Fourth*, in other part of India, *L. speciosa* is considered as a secondary host plant for *A. mylitta*, but the results of present study clearly indicates that it is as good as *T. arjuna* and adds one more primary host plant for successful commercial rearing of *A. mylitta* by forest dependent people in Uttarakhand.

*Fifth*, the results on multiple trait evaluation index analysis (Table 5.241) on forty variables of *A. mylitta* has also proved that *L. speciosa* is better host plant than *T. arjuna*, because it scored higher cumulative values of E.I. than *T. arjuna*.

### 6.3.6 Shell ratio of male and female cocoons

The quality of cocoons as a raw material mainly depends on its shell ratio. As a whole cocoons consist a pupa inside. Therefore, it is essential to know the ratio of whole cocoon weight. Silk ratio provides a fair indication to the quantity of raw silk that can be reeled from a fresh cocoon. Better shell ratio is the sign of better quantity of raw silk. Shell ratio also influences the cost of reeling. Hence, reellers would always prefer the cocoons high shell ratio. Srivastava *et al.*, (1994) suggested that silk ratio (SR percentage) is the second most reliable economic character after effective rate of rearing (ERR) for assessing the effect of forestry host plants and rearing season of *A. mylitta*.

During present study it was found that mean shell ratio of ♂ and ♀ cocoons differ significantly between rearing seasons, among host plants and their interactions (P<0.05). As reported by Dash *et al.* (1994), host plants, seasons and their interaction influence the cocoon shell weight of wild silkworm *Antheraea paphia*.

Further, it is evident that cocoons produced in second rearing season showed higher cocoon shell ratio on all the forestry host plants. Deka *et al.* (2011) and Sengupta *et al.* (2002) had also recorded significantly higher SR percentage of Daba
ecorace of *A. mylitta* in second rearing season than first in climatic conditions of Ranchi. They opined that the superiority of second crop to the first crop might be due to prevalence of optimum temperature and humidity regime for *A. mylitta*.

In our experimental rearing, *T. alata* produced cocoons having highest cocoon shell ratio, followed by the cocoons of *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae. Whereas, minimum shell ratio was shown by the cocoons of *L. tomentosa* and *T. chebula* fed larvae. Deka and Kumari (2013) had also assessed effect of six forestry host plants viz., *T. tomentosa*, *T. arjuna*, *T. bellirica*, *T. chebula*, *L. speciosa* and *L. parviflora* on cocoons characteristics of *A. mylitta* in the agro-climatic conditions of Ranchi, Jharkhand. In their study, performance of *L. speciosa* on cocoon productivity and silk ratio of *A. mylitta* was found comparably higher to *T. tomentosa* and *T. arjuna*. They further reported that the leaves of *T. arjuna*, *T. tomentosa* and *L. speciosa* possess more leaf moisture, chlorophyll, proteins and carbohydrates contents that support better larval growth of *A. mylitta* in comparison to its rearing on *T. bellirica*, *T. chebula* and *L. parviflora*. Like the results of present study, Kumar *et al.* (2009) had also found *L. speciosa* as one of the most suitable host plants for *A. mylitta* in view of SR percentage, especially for first rearing season.

Further, the results of present study are also supported by the findings of Kumar *et al.* (2006), who had found maximum SR percentage of 12.59 % on *T. arjuna*, followed by 12.12 %, 10.97 % and 9.58 % on *T. tomentosa*, *L. speciosa* and *T. chebula*, respectively. Whereas, Jolly (1966) and Jolly *et al.* (1974), had found tough and thick-shelled cocoons of *A. mylitta*, reared on *S. robusta* rather tougher than *T. tomentosa* and *T. arjuna*. Present study indicates that *L. tomentosa* reared cocoon showed lowest shell weight in both the seasons.

**6.3.7 Weight of male and female pupae**

Pupal stage is the most crucial stage for adult life of *A. mylitta* (Dash *et al.*, 2012). Pupal stage is a quiescent and non-feeding stage that is adapted to survive the unfavourable environmental conditions (Gordon, 1999). Quality of *A. mylitta* progeny largely depends on the quality of pupae that governs grainage parameters of parent stock (Gowda *et al.* 1988 and Govindan *et al.* 1990). Furthermore, the percentage of pupae resulting on a host plant is one of the major criteria for evaluating the quality of the food material (Bhattacharya and Pant, 1976).
Irrespective of the host plants and rearing seasons, it has been observed in the present study that mean weight of ♂ pupae is always lower than ♀ pupae. Panda (1972) had also reported same trend in case of *A. paphia* and Xue et al. (2009) in case of *Spodoptera litura*. Further, it was found that mean weight of ♂ and ♀ pupae differ significantly between rearing seasons, among host plants and their interactions (P<0.05). Devaiah and Dayashankar (1982) had also reported same results in case of *Samia cynthia ricini*.

The highest mean weight of ♂ and ♀ pupae was recorded by *T. alata* fed larvae, followed by *T. tomentosa, T. arjuna* and *L. speciosa* fed larvae; whereas, lowest pupal weight was observed in the replications of *L. tomentosa* and *T. chebula* fed larvae. Dash et al. (2012) had also conducted biometric study of *A. mylitta* pupae raised on different forestry host plants at lower, medium, and higher altitudes in Odisha. Their study indicated that *A. mylitta* larvae reared on *S. robusta* showed significantly highest values on all the pupal growth parameters. The gradation of eight food plants in respect of the pupal growth of *A. mylitta* was found as *S. robusta > T. alata > T. arjuna > Z. jujuba > L. parviflora > A. latifolia > T. bellirica > S. cumini*. Further, Dash et al. (1994), Nayak and Guru (1998a), Rath (2000), and Reddy et al. (2012) had also found a significant difference in average weight of ♂ and ♀ pupae of *A. mylitta* reared on different forestry host plants in different agro-climatic conditions.

Sengupta and Barah (1991) reported that the pupal weight is the best and genuine estimator for fecundity in non-mulberry silkworms. The previous works of Ahsan and Khannajain (1976) with *A. mylitta*, Sengupta and Barah (1991) with *A. assama*, Nagalakshmmamma (1987) with *P. ricini*, Mukerjee et al. (1983) with *B. mori* had also shown positive correlation between weight of the ♀ pupae and their total fecundity.

### 6.3.8 Silk filament length

Silk filament length or length of cocoon fibre or bave indicates reelable silk filament length of a cocoon and size of reel measures it. Filament length of cocoon shell is as important as the shell ratio. Generally, it is said that longer the silk filament, the greater is the weight of cocoon silk and shorter is the reeling discount. Silk filament length of the cocoon determines the workload, rate of production, evenness of the silk thread and the quality of the output (Somashekar, 2003).
It was found that mean silk filament length of *A. mylitta* differed significantly between rearing seasons, among host plants and their interactions (P<0.05). Further, during second rearing season, the mean silk filament length was found higher as compared to first rearing season. Sengupta *et al.* (2002) has also recorded significantly higher filament length of Daba ecorace of *A. mylitta* in second rearing season than first rearing season in Ranchi condition.

During present study, the highest mean silk filament length was observed in the cocoons of *T. alata* fed larvae, followed by *T. tomentosa, L. speciosa* and *T. arjuna* fed larvae; whereas lowest mean silk filament length was observed in the replications of *L. tomentosa*, followed by *T. chebula* fed larvae. Kumar *et al.* (2006) had also carried out bioassay studies with different accessions of *Terminalia* and *Lagerstroemia* species in Ranchi conditions and found maximum filament length of 814 m on *T. arjuna*, followed by 724 m, 556 m and 487.5 m on *T. tomentosa, L. speciosa* and *T. chebula*, respectively.

### 6.3.9 Non-breakable filament length

Non-breakable filament length (NBFL) depends on reallability of the cocoons; if the reallability is better, NBFL is on higher side and vice-versa. NBFL determines the number of casting required per minute under given reeling speed. Thus, higher NBFL gives better productivity and quality of the raw silk. NBFL is very essential to determine the filament continuity; as inferior quality cocoons results in more number of breaks (Somashhekar, 2003). It is reported that Daba ecorace of *A. mylitta* has maximum reliability among its all the eco-races (Kumari, and Roy, 2011).

In current study, it was found that NBFL of *A. mylitta* differ significantly between rearing seasons, among host plants and their interactions (P<0.05). Further, during second rearing season, we found higher mean NBFL as compared to first rearing season. Sengupta *et al.* (2002) had also recorded significantly higher NBFL of Daba ecorace of *A. mylitta* in second rearing season than first in Ranchi conditions.

During present study, it has been observed that the highest mean NBFL was recorded by *T. alata* fed larvae, followed by *T. tomentosa, L. speciosa* and *T. arjuna* fed larvae. Kumar *et al.* (2006) had also found maximum NBFL on *T. tomentosa*, followed by *T. arjuna, L. speciosa* and *T. chebula.*
6.3.10 Raw silk recovery percentage

Raw silk recovery percentage is defined as the amount of raw silk that is recovered from the given quantity of cocoons. It is the ratio of raw silk weight to cocoon weight expressed as a percentage (Somashekar, 2003). Naturally, this is the most important point of consideration from a reeler point of view, because it has direct connection with the price to be fetched for cocoons and realised cost of production of raw silk.

In current study it was found that raw silk recovery percentage of A. mylitta differed significantly between rearing seasons, among host plants and their interactions (P<0.05). Further, higher mean raw silk recovery percentage was recorded during second rearing season as compared to first. Sengupta et al. (2002) had also recorded significantly higher average silk recovery of Daba ecorace of A. mylitta in second rearing season than first in Ranchi conditions.

In present study, the highest mean raw silk recovery percentage was observed in the cocoons of T. alata fed larvae, followed by L. speciosa, T. tomentosa and T. arjuna fed larvae. Whereas, Dash et al. (1992) had found superior raw silk recovery percentage of A. mylitta on T. tomentosa in both the rearing seasons. Their gradation of food plants with regard to raw silk recovery in decreasing order was: T. tomentosa, T. arjuna, Z. jujuba, S. robusta, L. parviflora, and A. latifolia. Further, Rath et al.,(1997) had found that the larvae fed on T. tomentosa produced higher silk than those were fed larvae on T. arjuna.

6.3.11 Filament denier

Filament denier indicates the thickness of the silk filament. The denier of the cocoon filament is not constant throughout its length and varies depending upon its position in the cocoon shell. Normally, the filament denier is coarser at the outer layer and becomes finer towards the inner layers. From the raw silk quality point of view, it is always desirable to have lower denier values (more fine) of the silk filament (Jolly et al., 1979).

In present study, it was observed that mean filament denier of A. mylitta differed significantly between rearing seasons, host plants and their interactions (P<0.05). Further, during second rearing season, the mean filament denier was found lower (superior silk filament) as compared to first rearing season. Sengupta et al.
(2002) had also recorded significantly lower denier of Daba ecorace of *A. mylitta* in second rearing season than first in Ranchi conditions. In contrary to our findings, Barah *et al.* (1988) reported that silk denier of *A. assama* did not show any variation irrespective of the rearing seasons.

The lowest mean filament denier was shown by *T. tomentosa* fed larvae, followed by *L. speciosa*, *T. alata* and *T. arjuna* fed larvae. Our results are supported by the findings of Kumar *et al.* (2006), who found lowest filament denier in *T. tomentosa* fed larvae, followed by *T. arjuna*, *L. speciosa* and *T. chebula* fed larvae.

**6.3.12 Required number of cocoons to produce 1 Kg of raw silk**

Required number of cocoons to produce 1 Kg of raw silk provides commercial trading information to the reelers and the lower value of this trait is more worthy. It was found that mean required number of cocoons to produce 1 Kg of raw silk by *A. mylitta* differ significantly between rearing seasons, host plants and their interactions (P<0.05).

Results of present study also indicate that during second rearing season, it required lesser number of cocoons to produce 1 Kg of raw silk as compared to first rearing season. Sengupta *et al.* (2002) had also recorded significantly higher raw silk yield/1000 cocoons of Daba ecorace of *A. mylitta* in second rearing season than first rearing season.

Further, the lowest requirement of cocoons to produce 1 Kg of raw silk was recorded by *T. alata* fed larvae, followed by *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae. Results of the path coefficient analysis carried out by Siddiqui *et al.* (1989) revealed that larval weight of *A. mylitta* has direct and positive effect on required number of cocoons to produce 1 Kg of raw silk. Our results have also shown that *T. alata* fed larvae exhibited higher larval weight, followed by *T. tomentosa*, *L. speciosa* and *T. arjuna* fed larvae that were equally translated to production of absolute silk weight from their respective cocoons.